REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	22.Oct.98	MAJOR REPORT

4. TITLE AND SUBTITLE
MAJOR REPORT TITLE: SINGER'S THEORIES

5. FUNDING NUMBERS

6. AUTHOR(S)
CAPT PARSONS JAMES C

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
CREIGHTON UNIVERSITY

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
THE DEPARTMENT OF THE AIR FORCE
AFIT/CIA, BLDG 125
2950 P STREET
WPAFB OH 45433

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
98-021

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Unlimited distribution
In Accordance With AFI 35-205/AFIT Sup 1

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

19981119 040

Chart pages

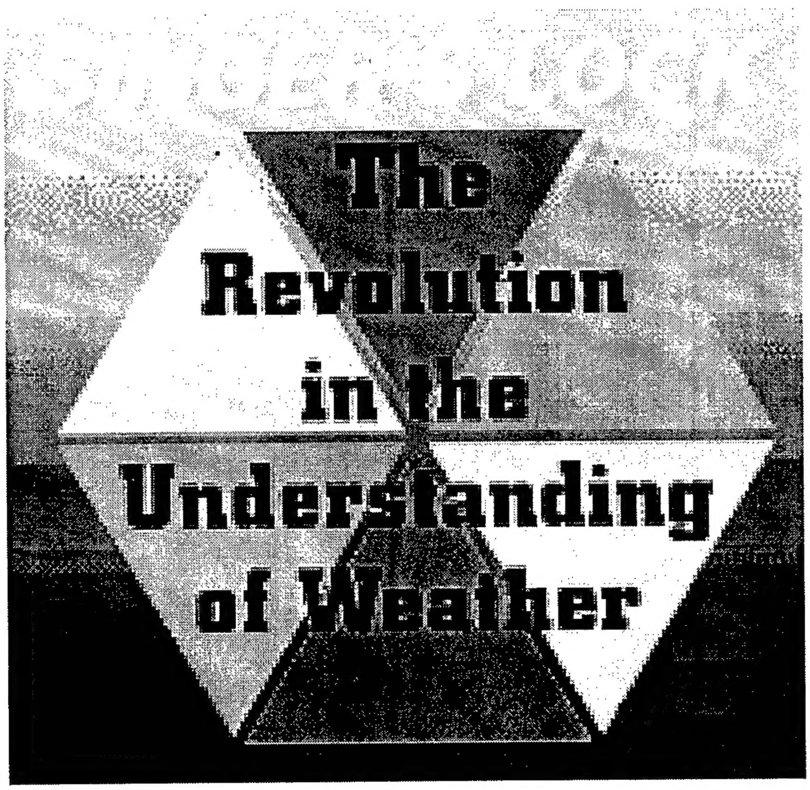
Reproduced From
Best Available Copy

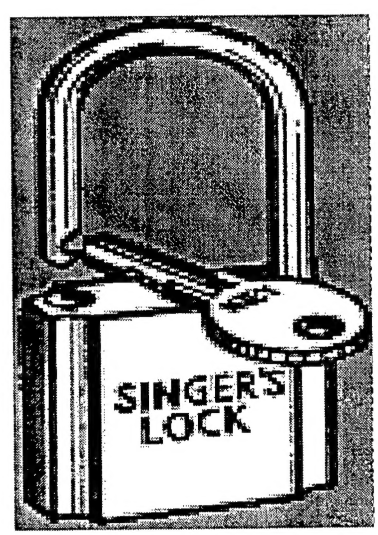
DTIC QUALITY INSPECTED 4

14. SUBJECT TERMS	15. NUMBER OF PAGES
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

"Singer's Theories"





Jim Parsons
Dec 1, 1997

ATS 795
Project Advisor: Dr Dean Morss

Singer's Theories

James C. Parsons

ATS 795 Paper

For Dr. Morss, Department of Atmospheric Sciences, Creighton University, Omaha, Ne.

ABSTRACT

This paper discusses Oscar Singer's theories in his book "Singer's Lock-The Revolution in the Understanding of Weather". I mainly recapitulate and condense his theories as well as adding thoughts on his revelations. The essence of the book, and this paper, is the acknowledgement that all the surface pressure systems in the atmosphere are connected in a symmetry and can be shown in a circumferential or radial (or both) relationship. This symmetry exists in both distance and radial relationships. After some initial groundwork and clarification on waves, symmetry, quantum units, and the polar stereographic map, we review several charts from his text displaying this relationship. It becomes obvious that there is a symmetrical relationship throughout the hemisphere for these pressure systems. Since all the surface pressure systems are tied to the upper levels of the atmosphere, we can conclude that this relationship exists in three-dimensional also.

So why haven't you heard about this "Revolution"? Mr. Singer's publication has not been accepted in the scientific community due to the use of the polar stereographic map projection, but this doesn't discount the obvious relationships shown on the charts. Although this "revelation" is noteworthy, it doesn't help an operational forecaster make a forecast. The amount of time required to analyze all the systems recognize the relationships, and the fact that polar stereographic charts are not in common use, tends to limit the operational use of this theory and any application thereof. Mr. Singer is currently in the process of obtaining grant money for the publication of a subsequent book revealing how one can use this relationship to make a timely forecast of pressure center positions. Until that time, us operational forecasters will have to continue to work with current technologies and techniques.

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Singer's Theories

I. PURPOSE STATEMENT.

During this semester I've read numerous publications by Oscar Singer regarding the movement of pressure systems on a hemispheric scale. Oscar Singer's research culminates in several publication's consisting of his capstone book titled "Singer's Lock, A Revolution in Weather Forecasting", published in 1985 and seven (7) supplemental volumes titled "The Bible(s) of Weather Forecasting". Since my atmospheric science program is centered on "Analyses and Forecasting", I'll recapitulate key parts of his theories and provide my interpretation as it applies to the operational meteorologist in today's environment.

I'm not aware of any other publication that describes the relationships of pressure systems as Mr. Singer has in his publications. These publications have met with resistance and are therefore somewhat controversial. I am not so much concerned with the exactness of the applied physics of his research, but more with an eye on the operational applications of his techniques. Therefore the approach I will take in this paper is geared towards the applicability of this "revolution" of forecasting the weather. Time constraints limit me from developing procedures to apply his technique in this paper, but I hope to do so at a later date. To that end, the information contained in this paper, unless noted, is Mr. Singer's. I'm simply trying to take a revolutionary idea/theory and apply it to the art of forecasting the weather in an operational environment.

II. Background.

As a Major in the United States Air Force during World War II and until 1953, Oscar Singer served as a weather officer, and learned first-hand the crucial life and death importance of accurate weather forecasting. His mission as a military meteorologist was to save lives by getting the forecast right. That remains his motivation today.

Mr. Singer first studied meteorology as an Aviation Cadet at the University of Chicago under Carl Rossby, and advanced meteorology at UCLA under J. Bjerknes. With additional training in advanced mathematics, chemistry, and electronics, he learned to respect and appreciate sound science as fundamental to understanding weather and forecasting. He published his book "Singer's Lock, A Revolution in Weather Forecasting" as a result of his observations in 1966, and thereafter, of how the atmosphere reacts.

III. The Polar Stereographic Map

To baseline his forecasts, Mr. Singer used the Polar Stereographic map. He goes in to quit a bit of detail defining and describing this map projection. This detail can be attributed to two reasons. The projection was the primary map of the 50's-80's and is hence used in his text. And the fact that when he attempted to publish the text in the 70's his theory was debunked based on the fact that the techniques of connecting systems with straight lines on this projection could not be carried over to other projections thus disqualifying the "Lock" as a physical law. This disqualification led to him buying a used press and publishing the text himself. The book goes into great detail to explain this projection and how it applies to his techniques. So the key is to believe this projection is valid for the following analyzes of pressure systems by drawing straight lines on this projection map and to understand some facts about using a projection of a sphere onto a flat surface (chart).

The following are some key points and figures from his text on the Polar Stereographic map:

Polar stereographic maps are used (among other reasons) because:
a. A circle on a sphere is reproduced exactly as a circle on the map.
b. All lines of latitude and longitude cross at 90° angles everywhere on the map in the same manner as they do on the surface of the Earth.
c. It is the best map available to show an area as large as a hemisphere.

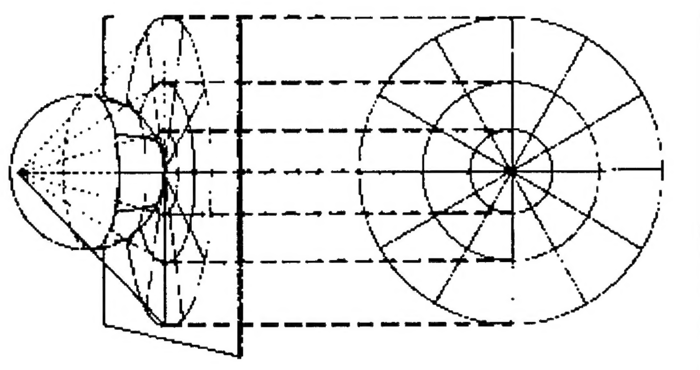


Figure 1.
Light projected from the south pole onto a flat transparent screen, which is tangent to the north pole, shows lines of longitude (which are great circles) as straight lines; while the circles of latitude (which are small circles except for the equator) show as perfect circles.

When two straight lines intersect on the flat map, regardless of length, they can be considered as the intersection of the arcs of two different circles on the surface of the sphere. These straight lines on the polar stereographic map can be interpreted in three different ways:
a. When we go a distance of 5° latitude (300 nautical miles) from any point on the Earth's surface we are actually moving along a curved arc. From a practical standpoint, this curved arc is usually considered as a straight line (in a plane) as

long as the distance is 5° or less; therefore, the angle between two straight lines that fall within a radius of 5° on the flat map is the same as the angle on the Earth's surface, with only a slight inaccuracy that is tolerable in weather analysis.
b. Straight lines on a flat map can be considered as projections of arcs of circles on a sphere, where the circle goes through the point of projection (the South Pole).
c. The two points at the end of a straight line on the map can be considered as the ends of a projected chord of the sphere.

Stereographic maps are used not only in weather, but also in many other fields. They are used for mapping crystal faces in crystallometry, and the mapping of geological structures in the field of geology. They have used straight lines on their maps for over a century. This is the first time that attention has been focused on the characteristics of a straight line on a polar stereographic map in meteorology. The significance of straight lines will be seen in the analysis we will make of weather patterns later on in the text.

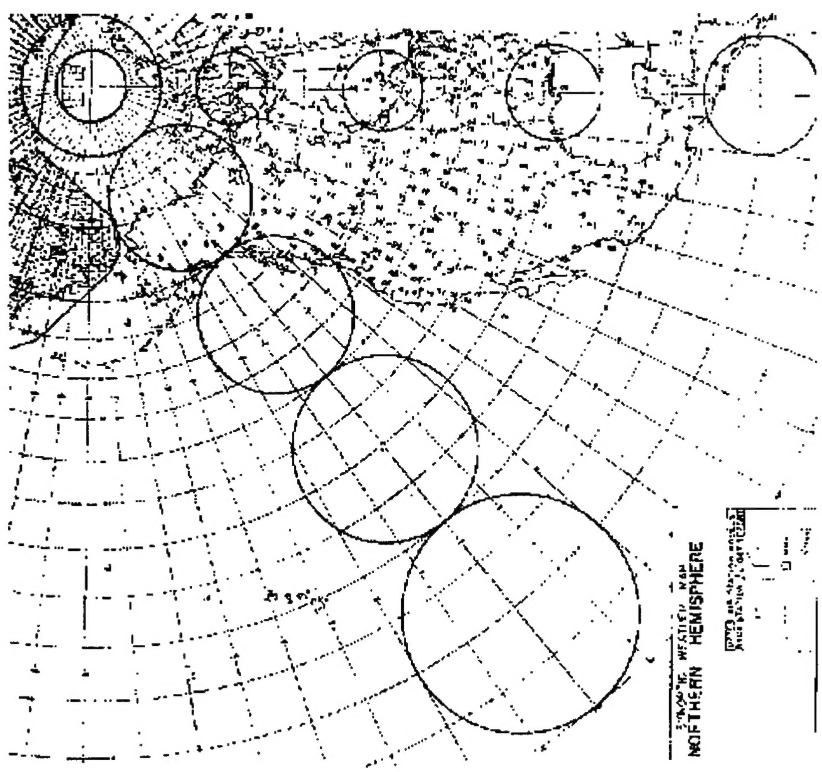


Figure 2.
Above is a partial polar stereographic map with two sets of circles, one with a radius of 5°, and the other with a radius of 10°. One circle for each radius is centered at the North Pole, 70°, 50° 30°, and 10° latitude.

The stereographic map possesses the important property that shape is preserved at a point, since every point is stretched equally in all directions like

any point on the surface of a rubber balloon. If a face is painted on a round rubber balloon, we will see the same face when the balloon is blown up, but larger in size. The point at the tip of the nose (and all other points) is stretched equally in all directions. We still have the tip of a nose in the larger blown up version, but the tip occupies more area. Figure 2 has been drawn to give a clearer visual picture of this type of distortion on the weather maps used as examples in this book.

On the surface of the Earth, all circles of equal radius are perfect circles, and each one covers the same area. Obviously, Figure 2, seems to contradict this fact. The error in this figure is created by the map projection, and the amount of error in the size of the circles can be calculated with the aid of equations provided in the text.

Figure 2 was used to illustrate the distortion on this map projection from the equator to the North Pole. Although this distortion can be corrected (as shown in his book), we just need to be aware of it when working with the following maps and techniques.

IV. Waves and Equilibrium

A section on waves and wave effects is introduced to relate the movement of the atmosphere in its entirety. Not so much as waves in the flow of air, but as peaks and valleys of pressure. How it all intertwines and as one moves, so must another. With this "push" movement, caused by a force, there must be an equal "pull". These changes in the forces acting on the pressure systems will relate in specific angles and distances. These relationships form the foundation of Singer's Lock.

Some articulate descriptions by Mr. Singer follow:

Usually, every material object can find at least one position in which it can remain at rest. This position is called the position of equilibrium. Any small outside disturbance (such as a push, pull, knock, etc.) will make the body move out of the equilibrium position to a new position. When that happens, the forces on the body are no longer evenly balanced and the body experiences a restoring force which tends to pull it back to its original position. This restoring force starts by dragging the body back toward its original equilibrium position. In time it reaches this position, but since it is moving with a certain amount of speed, it overshoots the position and travels a certain distance on the other side before stopping. Now it experiences a new force tending to pull it back; again it gives in to this force, picks up speed, overshoots the equilibrium position, and so on, until it stops due to friction or other forces. This kind of motion is called an oscillation. When a body moves a very small distance, the motion is called a vibration. This type of vibratory or oscillatory motion is defined as simple harmonic motion.

The spacing of all vortexes and other significant features such as troughs and ridges on a weather map over an entire hemisphere have been falsely considered, by meteorologists, to be of a random nature. Therefore, it is the main purpose of his text to prove that the positioning of vortexes is not random, but is beautifully organized.

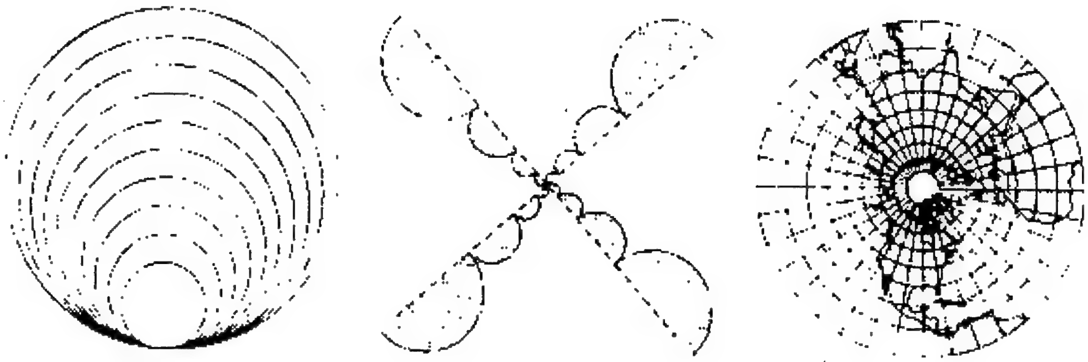
V. Symmetry

We touch on symmetry to establish a baseline of understanding to help illustrate the relationships depicted on the following charts. Once we agree on the fact that everything in the atmosphere is related, in some sense, we will more easily see, understand, and accept Mr. Singer's theories. The quantum unit, next section's topic, is based on his definitions of equilibrium and symmetry. With that he actually defines the fundamental unit for weather systems. He explains this approach as follows.

Dilation symmetry is the enlargement or reduction of a figure along lines radiating from a central point. Figures 3-5 show examples of dilation symmetry. Any seemingly random or disorderly activity in nature becomes very reasonable and orderly once we understand all the processes involved. Every movement of any storm center or high pressure center on the Earth's surface must be exactly counterbalanced by a very orderly movement of an air mass somewhere else on the globe. There is no such thing as random spacing of highs and lows over the surface of the Earth. Every vortex takes into account what every other vortex on the Earth is doing, before making its own move. Looking at the examples in of charts, it almost seems as if the vortexes are in communication with each other--as if they were living entities.

Every entity in the Universe, when reacting to surrounding entities, tries to reach the "position of equilibrium" or symmetry, which is the simplest arrangement in nature. When outside energy is injected into a system, the entities that were in equilibrium will be forced out into asymmetric (nonsymmetrical) patterns, and then attempt to swing back again into a symmetric or equilibrious pattern. Similarly, defects that occur in the symmetry of weather patterns, are signals of change.

His explanation leads us to the obvious conclusion that a change is size or intensity, which is typically related to size, would indicate an adjustment to a given system through equilibrium represented by symmetry. This thus leads us to his discussion on establishing the fundamental quantum unit.



a. b. c.

Figure 3.
Examples of Dilation Symmetry.

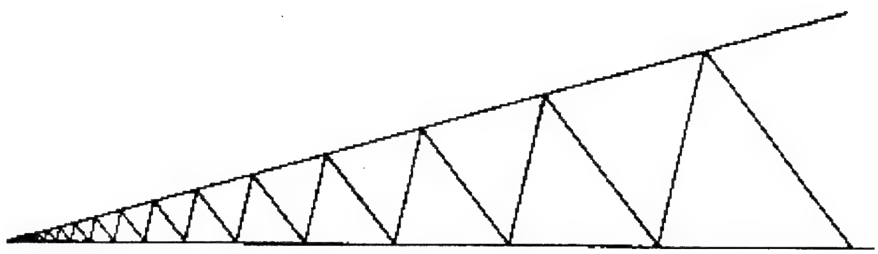
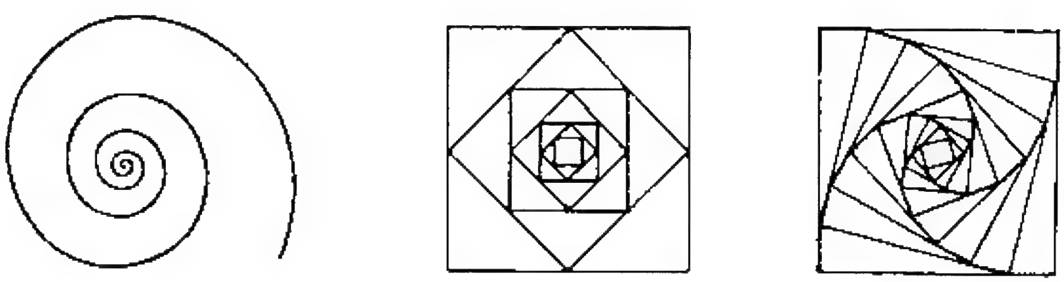


Figure 4.
Dilation with a reflection.



a. b. c.

Figure 5.
Dilation with rotation.

VI. Quantum Units and Angular Numbers

This section breaks out, numerically, the relationships of pressure systems on a chart. How each is a quantum unit or a multiple thereof. His theory is based on the distance and angle of the pressure systems from one another. Understanding that a baseline size exists could help one see (forecast) where a change can be expected. This section is instrumental to understanding his theory. So the following is almost verbatim from his text.

Everything in the Universe comes in packages (quantum units), large or small; in a fixed range of sizes from one extreme, where it is never found in a smaller size; to the other extreme, where it is never found in a larger size. This applies to eggs, oranges, dogs, cats, men, women, and even stars in the heavens, etc. These larger packages or quantum units can always be broken up into smaller elementary quantum units.
The actual size of an object is determined by the forces acting on the object. We find that all living cells, depending on what type they are, vary little from a certain average size, and no cell can grow larger than a certain absolute magnitude. Some factors that can limit their size are gravity, surface tension, heat, and light.

So how does this explanation tie into our discussion?
Throughout the Universe it's known that most things come in packages, large or small. It would be surprising if weather vortexes (highs and lows) did not show a minimum size limit and that larger sized highs and lows would be multiples of the minimum or quantum sized vortex. There are tens of surface pressure systems covering the Earth every day. This total number must always be a whole, rational number, since there is no such thing as a part of a high or low. The smallest high or low at any given point in time could be considered as the elementary quantum unit. Any other high or low on the map would be of a size that is equal to, or a multiple of the baseline or fundamental quantum sized unit.

This principle of quantum size, as Mr. Singer visualized it, is that there are preferred sizes for a given vortex. If the vortex is not a quantum size, then it will change very rapidly (by pulses of growth or decay) to the next higher or lower quantum size (which can be 1, 2, 3, etc., times the basic quantum unit).

To establish this relationship of quantum units and to find the fundamental quantum unit for pressure systems, Mr. Singer developed a relationship called "Diffraction Grating". When converting wave numbers into distances on a polar stereographic map, the distance is expressed in degrees of latitude. One degree of latitude always represents the same distance of 60 nautical miles anywhere on the map. We don't use degrees of longitude to measure distance, because distance between any two-longitude lines varies when going from the pole to the equator. When we look at the weather map for 7 December 1950 (Fig. 9), we find that the closest distance between any two vortexes (high or low) is in the

range of approximately 3.75 degrees of latitude. Vortex centers #83 and #84 are separated by approximately 3° (Fig 9). He found that the 3.75° distance is the smallest quantum unit of spacing between any two vortex centers in the winter season (since fundamental sizes may possibly vary with changes in temperature). He also found that the use of 1.875° (half of 3.75°) will give greater detail, since half the distance between any two vortex centers can be considered as the radial distance of each of the vortexes in the direction of the line joining them. See Figure 6.

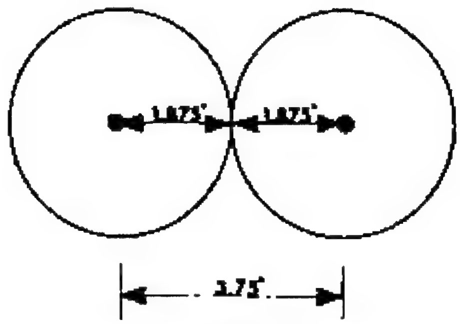


Figure 6.
Half the distance between two vortex centers will give an indication of the radius of each vortex.

Then he divided the 360° circumference of a circle by 1.875°, we get a wave number of 192 (360°/1.875°). Figure 7 gives the value in degrees of each of the 192 divisions. We note that the angles of 30°, 60°, and 120° (and their sub-multiples) occur in this table and also the angles of 45°, 90°, and 180° (and their sub-multiples). These are the angles that occur in triangular, square, and hexagonal configurations. The occurrence of these angles on a weather map would be one of the indications that a regular geometric shape exists.

Figure 7.
(Below)
360° circumference divided by 1.875°.
192 wave numbers with there respective values.

01•01.875	33•061.875	65•121.875	097•181.875	129•241.875	161•301.875
02•03.750	34•063.750	66•123.750	098•183.750	130•243.750	162•303.750
03•05.625	35•065.625	67•125.625	099•185.625	131•245.625	163•305.625
04•07.500	36•067.500	68•127.500	100•187.500	132•247.500	164•307.500
05•09.375	37•069.375	69•129.375	101•189.375	133•249.375	165•309.375
06•11.250	38•071.250	70•131.250	102•191.250	134•251.250	166•311.250
07•13.125	39•073.125	71•133.125	103•193.125	135•253.125	167•313.125
08•15.000	40•075.000	72•135.000	104•195.000	136•255.000	168•315.000
09•16.875	41•076.875	73•136.875	105•196.875	137•256.875	169•316.875
10•18.750	42•078.750	74•138.750	106•198.750	138•258.750	170•318.750
11•20.625	43•080.625	75•140.625	107•200.625	139•260.625	171•320.625
12•22.500	44•082.500	76•142.500	108•202.500	140•262.500	172•322.500
13•24.375	45•084.375	77•144.375	109•204.375	141•264.375	173•324.375
14•26.250	46•086.250	78•146.250	110•206.250	142•266.250	174•326.250
15•28.125	47•088.125	79•148.125	111•208.125	143•268.125	175•328.125
16•30.000	48•090.000	80•150.000	112•210.000	144•270.000	176•330.000
17•31.875	49•091.875	81•151.875	113•211.875	145•271.875	177•331.875
18•33.750	50•093.750	82•153.750	114•213.750	146•273.750	178•333.750
19•35.625	51•095.625	83•155.625	115•215.625	147•275.625	179•335.625
20•37.500	52•097.500	84•157.500	116•217.500	148•277.500	180•337.500
21•39.375	53•099.375	85•159.375	117•219.375	149•279.375	181•339.375
22•41.250	54•101.250	86•161.250	118•221.250	150•281.250	182•341.250
23•43.125	55•103.125	87•163.125	119•223.125	151•283.125	183•343.125
24•45.000	56•105.000	88•165.000	120•225.000	152•285.000	184•345.000
25•46.875	57•106.875	89•166.875	121•226.875	153•286.875	185•346.875
26•48.750	58•108.750	90•168.750	122•228.750	154•288.750	186•348.750
27•50.625	59•110.625	91•170.625	123•230.625	155•290.625	187•350.625
28•52.500	60•112.500	92•172.500	124•232.500	156•292.500	188•352.500
29•54.375	61•114.375	93•174.375	125•234.375	157•294.375	189•354.375
30•56.250	62•116.250	94•176.250	126•236.250	158•296.250	190•356.250
31•58.125	63•118.125	95•178.125	127•238.125	159•298.125	191•358.125
32•60.000	64•120.000	96•180.000	128•240.000	160•300.000	192•360.000

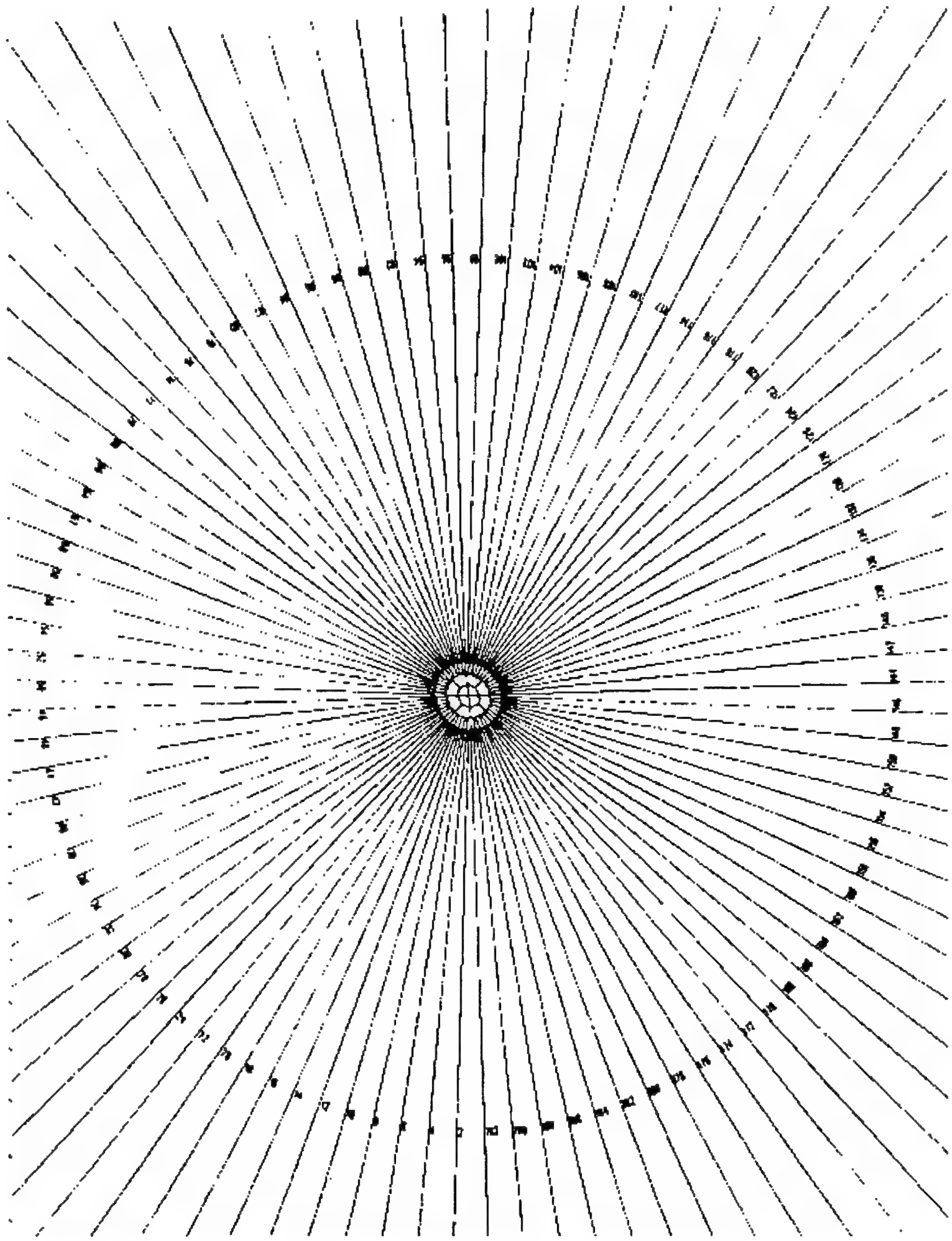


Figure 8.
A view of the "diffraction" tool used to construct the charts in this book.

Figure 8 is a reduced view of the tool, which is a protractor covering the full 360° circle with the unique feature of being divided into sectors that are all equal to 3.75°. The reason for using the 3.75° spacing, instead of the 1.875° spacing, is that it reduces the clutter of too many lines, especially near the center.
This tool, consisting of a transparency, may seem disarmingly simple. The unique feature, as you will shortly see, is that it is a "diffraction grating", or "tuning fork" for the weather map.

The 1.875° angle is used in two ways. First, as the harmonic element to test for resonance with other vortexes along the radial distance outward from a vortex and second, along the circumference of any appropriate circular ring.

A main purpose of his book is to establish that there is an order in the arrangement of all the features on a surface weather map- the "Lock" between the pressure systems.

VII. Explanation of the Charts

Before we actually try to figure out the relationships shown on some of Mr. Singer's charts, we need a brief explanation about them. He chose December 7, 1950 for two reasons. They were free from satellite observations or computer calculations and there was a significant number of well defined highs and lows available on the maps.
He used June 6, 1944 to show that the day of December 7, 1950 was not unique. That the relationships shown are evident in the less defined summer months also.

The Identification Map (Figure 9) assigns a number to every high, low, and col that he chose. There are additional points on the map that he could have included, but were not for the following reasons:
1. Their centers are poorly defined.
2. The additional cost in time, labor, and materials to make extra charts and to explain them.
3. Their use would not alter the major conclusions that are developed by the examples shown.

The order in which the numbers were chosen and the pattern formed by the numbers have no special significance.

Figure 10 is a listing of the latitude and longitude for each of the 104 points used in the Identification Map (Fig 9). These numerical values were measured on the master chart used to construct the charts in his book. The register crosses in the Identification map were located carefully, but the values indicated in the table take priority for accuracy in all cases.

Identification Chart

Figure 10

#	Lat.	Long.	#	Lat.	Long.	#	Lat.	Long.
1	8.4N	126.7E	36	61.1N	12.7E	71	74.1N	88.0W
2	6.7N	104.5E	37	62.7N	27.1E	72	65.3N	109.1W
3	23.3N	105.3E	38	68.0N	25.5E	73	61.9N	113.0W
4	25.1N	91.7E	39	72.5N	21.8E	74	53.9N	125.4W
5	22.5N	84.3E	40	75.9N	52.8E	75	66.4N	126.2W
6	17.0N	76.8E	41	71.1N	61.5E	76	55.3N	145.2W
7	23.7N	58.5E	42	68.1N	64.7E	77	45.0N	172.0W
8	17.8N	53.9E	43	71.0N	96.2E	78	37.5N	173.5W
9	2.8N	33.4E	44	80.7N	75.0E	79	28.0N	142.1W
10	14.8N	36.9E	45	81.0N	97.0E	80	27.1N	131.1W
11	16.5N	38.9E	46	58.6N	145.2E	81	38.0N	124.2W
12	34.1N	28.0E	47	39.0N	144.2E	82	37.6N	109.9W
13	42.8N	33.4E	48	44.6N	149.7E	83	45.0N	112.8W
14	42.1N	44.8E	49	48.1N	163.2E	84	48.0N	112.4W
15	48.5N	62.1E	50	51.1N	64.5E	85	48.8N	115.6W
16	50.9N	65.7E	51	53.2N	165.3E	86	55.6N	74.7W
17	51.8N	77.7E	52	60.2N	174.1W	87	53.3N	71.0W
18	52.2N	84.3E	53	66.5N	170.0E	88	50.8N	68.3W
19	51.9N	91.6E	54	69.2N	171.3W	89	45.2N	44.4W
20	28.2N	122.9E	55	76.2N	178.0E	90	28.4N	48.0W
21	27.1N	134.9E	56	80.0N	152.8E	91	38.6N	84.1W
22	34.7N	133.3E	57	77.2N	140.0W	92	41.5N	86.1W
23	43.4N	129.4E	58	82.9N	120.5W	93	43.6N	91.0W
24	46.8N	132.0E	59	76.3N	56.2W	94	35.1N	97.4W
25	55.0N	115.0E	60	67.6N	26.8W	95	32.2N	105.2W
26	51.3N	110.3E	61	43.0N	5.8W	96	27.8N	105.9W
27	58.0N	104.5E	62	32.8N	23.2W	97	22.2N	103.3W
28	59.9N	47.0E	63	41.5N	24.9W	98	23.0N	94.9W
29	50.4N	35.3E	64	42.0N	34.0W	99	28.9N	93.8W
30	35.0N	7.1E	65	48.0N	31.4W	100	20.1N	71.3W
31	38.1N	6.9E	66	49.0N	25.1W	101	12.2N	77.8W
32	41.0N	6.9E	67	46.9N	19.8W	102	11.9N	83.9W
33	48.7N	11.7E	68	71.1N	66.3W	103	14.1N	91.1W
34	55.2N	3.0E	69	68.4N	78.0W	104	13.5N	109.5W
35	59.0N	2.5W	70	66.0N	84.8W			

Lat/Long for points on Identification Map.

The symmetry patterns shown in the charts are not affected by mountainous terrain or the open sea. They also are not affected by the size, shape, intensity, or distance between the highs and lows that make up the elements of the symmetry patterns. Mr. Singer used two types of analysis to verify his theories: Circumferential and Radial.

The analysis of December 7, 1950 is broken down into two major divisions, circumferential and radial. In the first division, each one of 30 different points on the map is subject to a harmonic analysis that exposes the circumferential patterns; while in the second division, he subjected them to a radial analysis. The circumferential patterns break up a circumference into different wave numbers depending on the number of diameters that are created.
The radial patterns are similar to different rings as we move out radially from the center of a disturbance. In this paper I've only chosen to use a few of his examples to show these relationships. We start with the circumferential charts.

VIII. Circumferential Charts

Each chart is labeled with the number of the high or low that is the central or nuclear vortex around which a symmetry pattern is drawn. Since this group of charts shows circumferential patterns, we look for patterns with rays that radiate outward around like the spokes of a bicycle wheel. We look for symmetry in the spacing of the rays from the nuclear vortex. The spacing of the spokes on a wheel can be described by the angular separation between the spokes. The dashed, dotted, or solid lines can be considered as the spokes of a wheel and the angular separation of the spokes or rays is given by a whole number called the angular number, which is an exact multiple of 1.875° (see Fig 10). Therefore, the angular separation between any two rays can be described as any number from 1 through 192. The value of this angular number can be read in angular degrees from the table in Figure 10.

The great circle distances are entered between the nuclear center and the ends of the rays of circumferential charts. This radial distance is also given in the same type of numbers as shown in Figure 10. The circumferential numbers are entered near the center of the nuclear vortex inside the angle formed by any two rays radiating out from the nuclear center. The radial numbers, on the other hand, are entered at the ends of the rays.

The angular numbers near the center of the nucleus represent the angles (when converted to degrees) between any two adjacent straight lines (each of which represents a small circle on the globe). What we see are symmetry patterns involving arcs or portions of small circles. The abbreviation **"cu"** is used when referring to the angular number units that can be measured between any two rays when working with circumferential type patterns; i.e. 14 circumferential angular units will be called 14 cu (14 times 1.875°=26.25°).

The radial distance, however, is given in angular numbers (which can be converted to degrees of latitude) that are a measure of the great circle distance between the central vortex and the point at the end of the ray. A line drawn to represent the great circle distance should be slightly curved on these polar stereographic maps, and cannot be represented by the straight line shown as a

ray (except when the line passes through the North or South Pole). The distance along the straight line of a ray is also slightly larger in value than the great circle distance--therefore the straight line is intended to only identify the end points between which there is a certain great circle distance. The abbreviation **"ru"** is used when referring to the units of the radial angular number that represents the true radial great circle distance.

Whenever there was any uncertainty as to the location of the center for any given vortex in the charts, the point that was finally chosen, was the point that gave the maximum number of symmetry relationships with the surrounding points. This, of course, was not the only factor considered in locating a center, but nevertheless, it was the most important factor. Important enough to state flatly that: identifying the maximum number of symmetry patterns surrounding a low or high will register the exact center of a low or high where the lines cross.

Now armed with an understanding and description of the theory and convention used, I selected four charts to review the circumferential relationships. The chart number reflects the pressure center used as the central point for symmetry and is based on the numbering convention used on the base or Identification Map (Fig 9).

Chart #58.

The exact point chosen as the center of #58. It has the shape of two separate ellipses joined together. Here we have a case of multiple centers with the dominating center located at or near the spot where the "H" is marked. On this chart we look at both the circumferential and radial relationships.

On one side of the straight line joining #81 and #40, there are two angular numbers of 14 cu that are opposite each other and two angular numbers of 34 cu in the middle. #40 has a radial distance of 11.3 ru, #39 has 12.5 ru, while #81 has 24 ru, which gives a ratio close to 2:1, if we use the average value of #39 and #40. #55 has a radial distance of approximately 6.5 ru, while #60 has 12.7 ru-this is almost 2:1 again.

#60, with a radial distance of 12.7 ru, compares closely with #39 at 12.5 ru, while both are symmetrical around point #34 at angles of 11 cu. We can't expect everything to be perfectly neat, since we do have a dynamic system that is not in perfect balance or equilibrium.

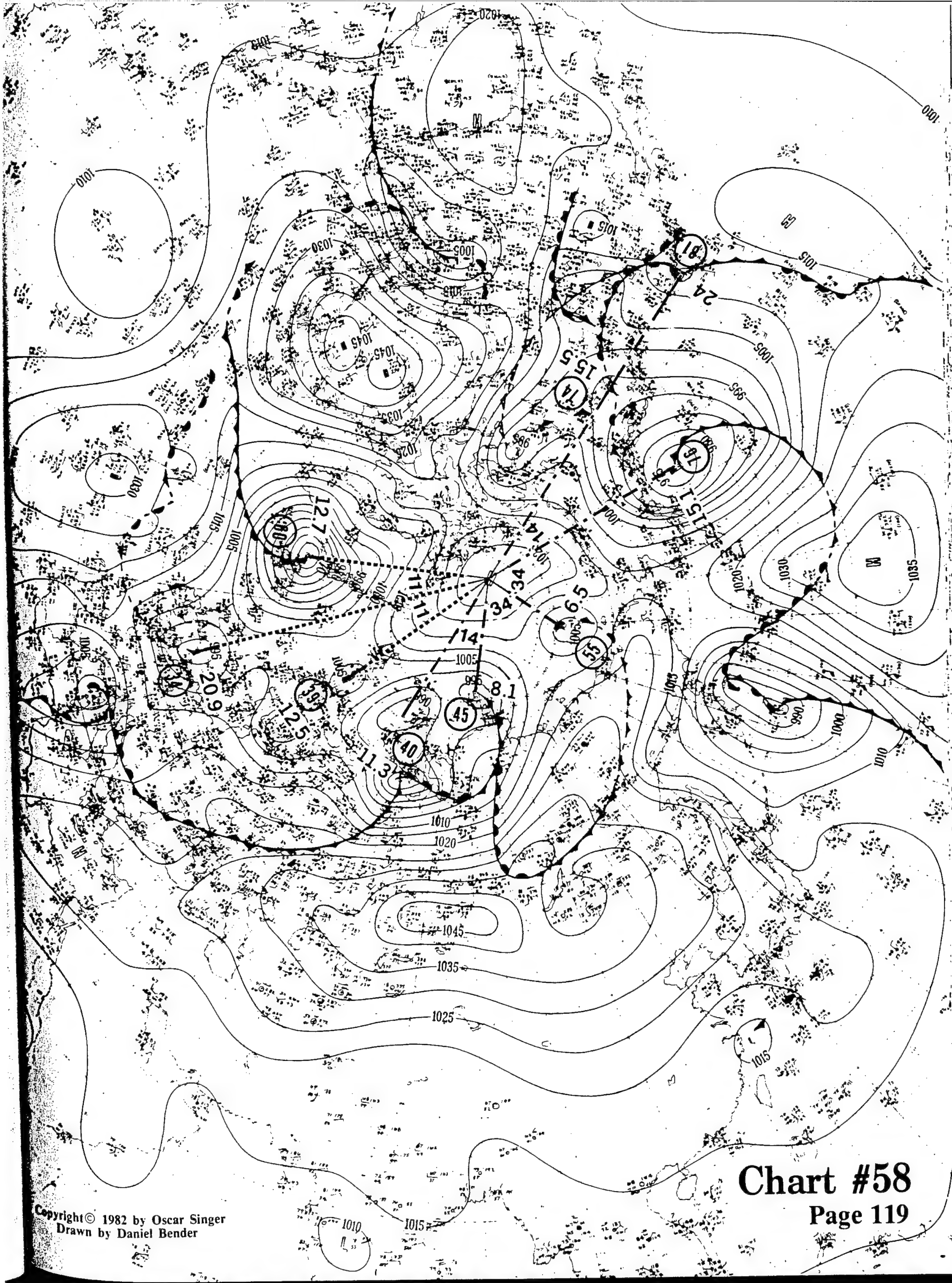


Chart #58

Chart 55A

In the symmetry pattern for point #55, we find that 6 is the common denominator of the angular numbers of 12, 18, and 36. This circumferential pattern has four 18's, one 36, two 12's balanced by one 24, and two irregular angles (14 plus 22 equal 36) to complete the ring of 192 numbers. The solid lines were drawn to three points to show that they are related by the angular numbers of 48, 64, and 80. These translate into 90°, 120°, and 150°, which are in the ratio of 3:4:5.

This chart was drawn to show a circumferential symmetry pattern of points around point #55, with no consideration of any kind as to the radial distance of each of these points from the center. But, careful scrutiny will show that point #58 is a great circle distance of 6.5 ru, #51 which is opposite is a distance of 12.5 ru, while point #76 is a distance of 13.3 ru; point #26 is a distance of 18.9 ru which is 3 times 6.5 approximately.

Point #46 is a radial distance of 11.2 ru from point #55, while point #86 is a radial distance of 21.6 ru (almost 2 to 1) from point #55. This is on a straight line joining three points. In addition, point #99 is 32.8 ru away, which is almost 3 to 1. Point #45 (8.1 ru) and point #77 (16.8 ru) are nearly 2 to 1. Point #6 (40.6 ru) is related to point #45 (8.1 ru) in the distance ratio of 5:1.

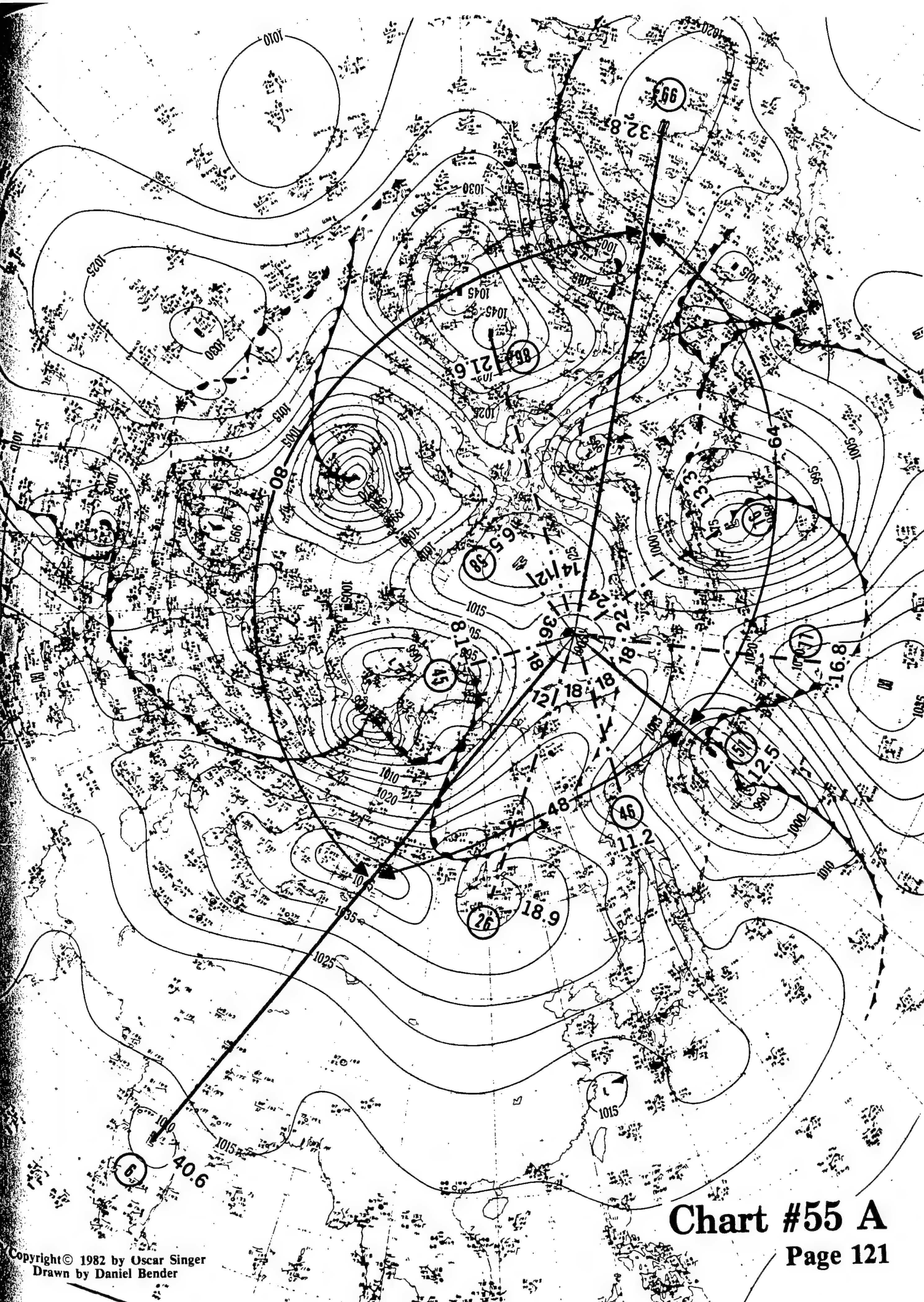
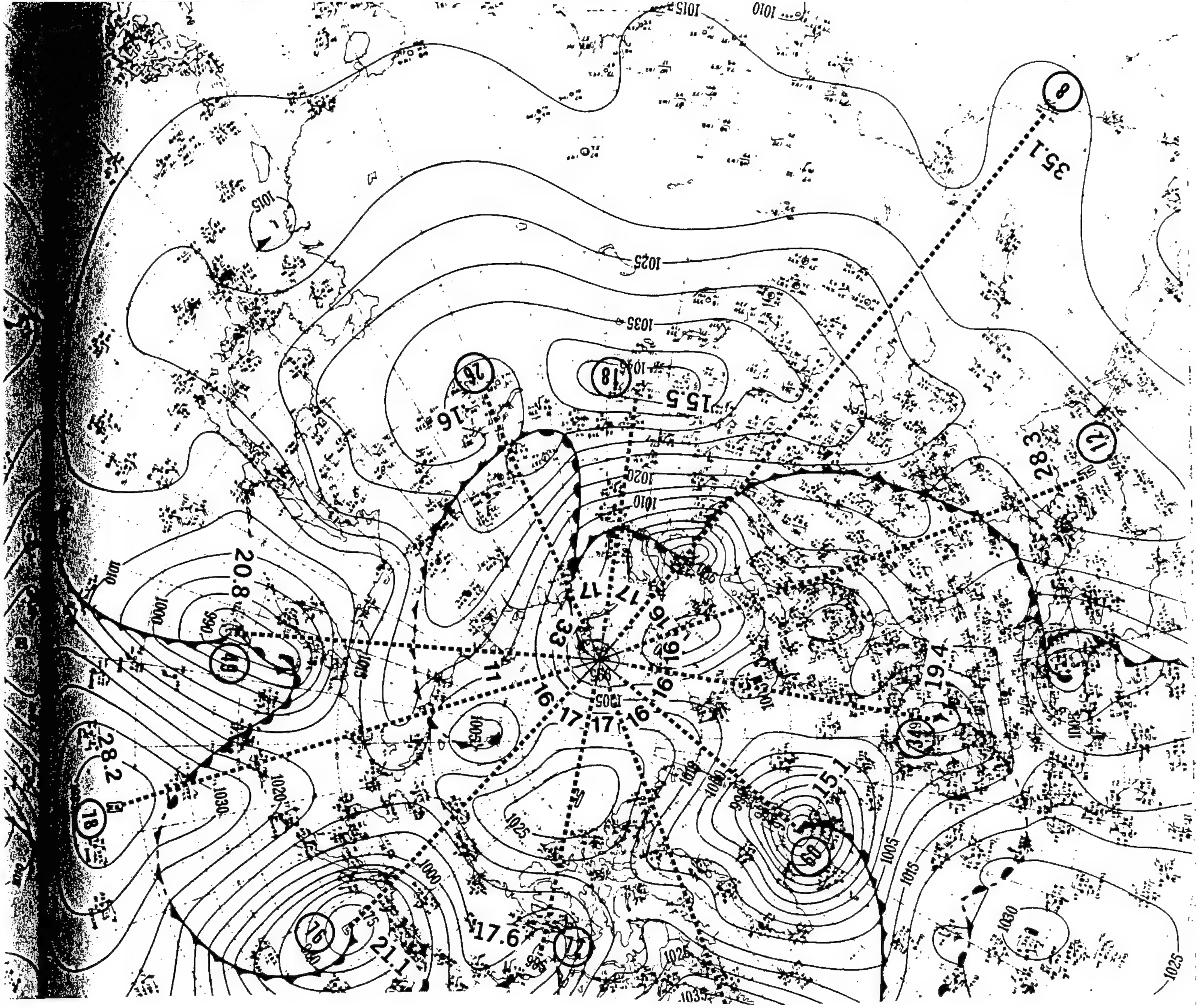
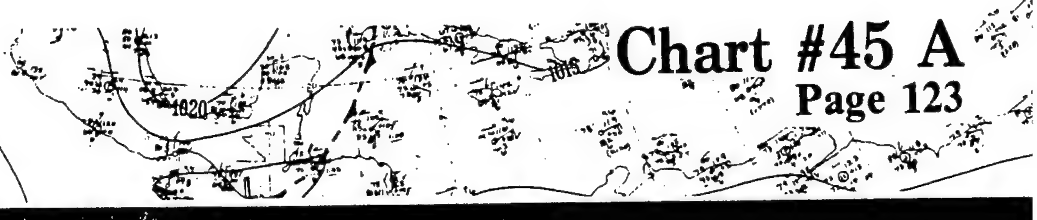


Chart #55 A

Drawn by Daniel Bender





Drawn by Daniel Bender

Chart #45 A

Chart 45A

The symmetries involve cu units of 16 and 17, with four 16's balanced on each side by two 17's each. There is a 33 left over, which is of course 16+17, and magically, the 11 that is needed to complete the sum of 192 cu of circumference, is one third of 33, for a ratio of 3:1

Now for radial distances. #72 (17.6 ru) is nearly opposite #8 (35.1 ru) for a ratio of 2:1. #78 with 28.2 ru is almost opposite #12 with 28.3 ru, for a 1:1 ratio. #60 with 15.1 ru is almost opposite to #26, with 16 ru, and #18 with 15.5 ru, which are close to a 1:1 ratio. #49 with 20.8 ru and #76 with 21.1 ru are virtually equal to 3x7; while #78 with 28.2 ru and #12 with 28.3 ru are about 4x7, which leaves #8 with 35.1 ru at 5X7.

Chart #45 B

From the principle of superposition of waves, we know that we can have independent waves occurring simultaneously. Each wave can do its own thing, as if there were no other waves around. In this analysis of point #45, we have extracted another symmetry pattern coexisting around the same point. Here we find that a large portion of the atmosphere of the Northern Hemisphere is resonating at an angular number of 10 around point #45. Of the nineteen points that are linked in this angular mode, we find that the centers of nine of the points at the ends of the rays are not controversial as to location and are very good hits. These nine are #42, #37, #34, #55, #90, #88, #93, #78, and #21. If the other ten points were removed, we would still find an unusual, balanced symmetry pattern, with the separation between rays at 10 cu or a whole number multiple of 10 cu. The ray that goes to #63 is not a perfect hit, but is slightly off to one side of the "H". This same ray passes right near #66, which is off by a similar amount, but in the opposite direction. What we have is an example where the ray for this angular number of 10 lies exactly between #63 and #66. This type of symmetry on both sides of a line is quite common and you can find it everywhere that you look on a weather map. This is an example of longitudinal glide reflection of the type shown in Figure 11 (below). So it is not unreasonable to consider that this ray, which passes between #63 and #66, can be added as an additional good hit to be added to the original eight.

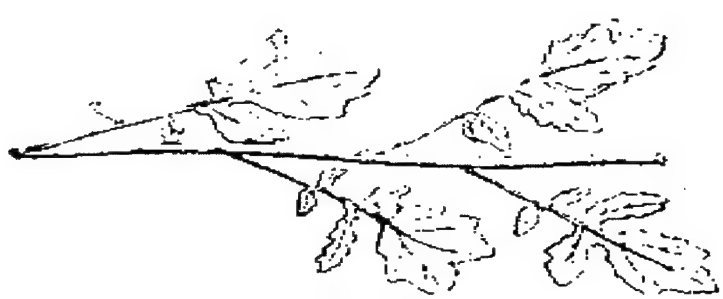


Figure 11.
Leaf reflection shows glide reflection symmetry.

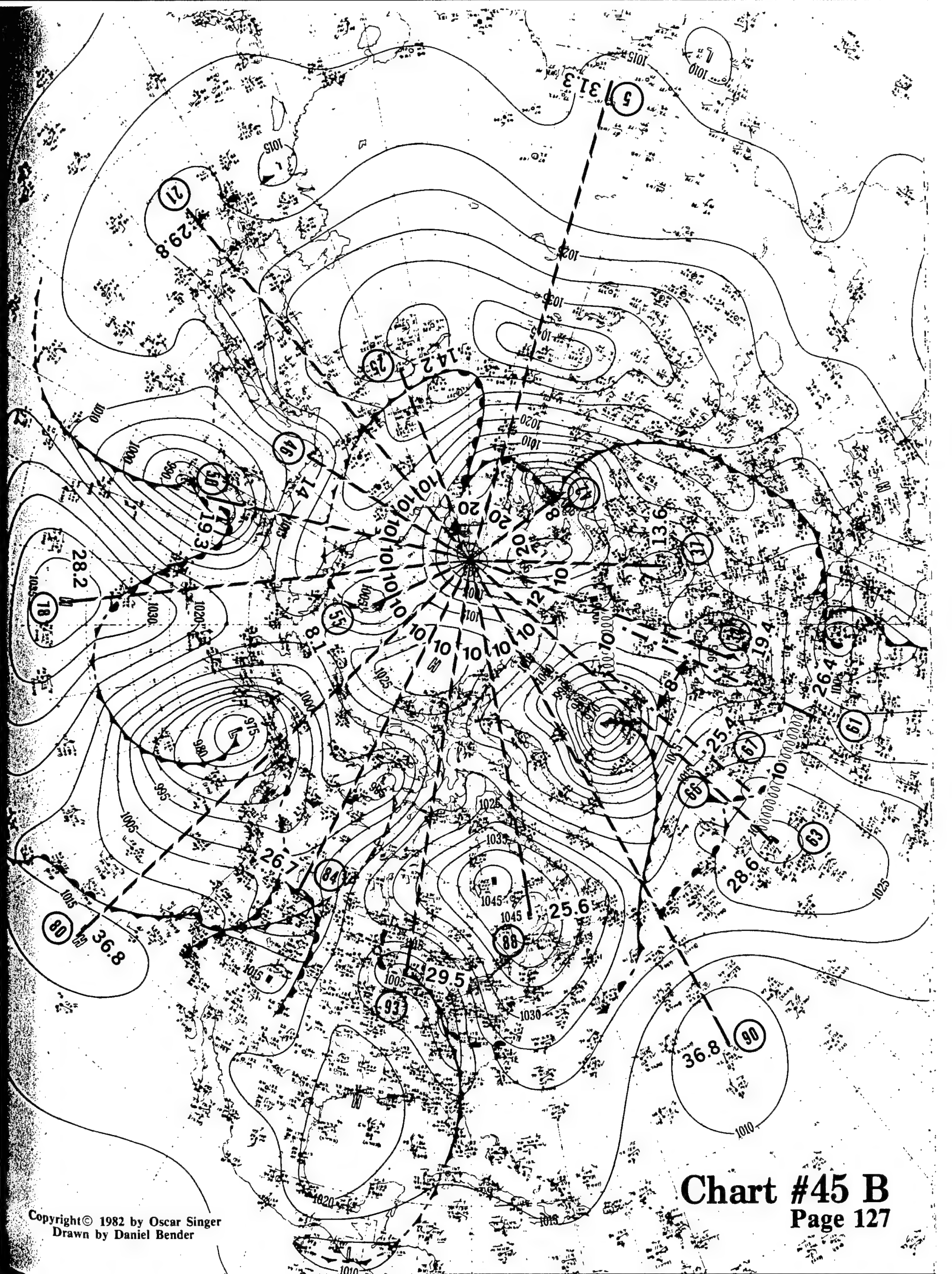


Chart #45 B

Drawn by Daniel Bender

Chart 45B (cont'd)

Points #46 and #25 are poorly defined, but their centers appear to be reasonably located on one of the rays for the angular numbers involving 10 cu. Points #5 and #80 are poor hits for the centers, but they have been entered as a matter of interest. #55 and #84 are very close hits, but not perfect. Most meteorologists would consider such small distances (as are involved in the close but not perfect hits) as being not discernible in any type of measurement they usually make. Any slight variance, however, stands out sharply in the light of the rules of Singer's Lock.

You might ask: "How do cols fit into these symmetry patterns?" You will find that cols do indeed fit into the patterns, empirically, as can be seen in the charts. Point #50 is the col between #49 and #51. Theoretically, there is no difficulty in understanding why. If the centers of highs and lows show an orderly arrangement in space, then the center point in between any two highs or lows must reflect a similar type of symmetry. Just from mechanical considerations alone; in the same way as the center point on a bar joining the two bells of a dumbbell.

Now we come to the fascinating points of #61 and #67. They represent the terminal ends of the symmetry pattern with 10 cu as the fundamental unit. When we go (in an easterly direction) 10 cu, exactly, from #63, we end up a slight distance to the east of the center of #61. The rays for #61 and #63 are joined with a symbolic coil or spring to illuminate the elastic nature of the termination. Likewise, when we go (in a westerly direction) 10 cu, exactly, from #34, we end up a slight distance to the west of the center of #67. In a similar manner, the rays for #34 and #67 are joined by a symbolic spring.

The symmetry of the way the pattern terminates is an interesting feature. There is an overshoot of two tiny remnant vortexes. The 192 cu of a complete circle should have left a remainder of 2 cu when 192 cu is divided by 10. Instead we have an overlapping at each end to eliminate the need for a remainder of two.

Of course, #45 is not the only disturbance in the hemisphere. There are other centers that are growing or decaying at the same moment in time. The ones that are stronger and are growing will tend to force other vortexes to line up into resonant nodes. The weaker disturbances will tend to lose control of the vortexes in their respective nodes. Whether any given low or high is moving towards any special nodal line or away from any special nodal line is determined by the resultant of the forces. The predominantly stronger and growing disturbances will naturally have a stronger influence. In summation, any vortex or col that is near any given line of symmetry will tend to move towards or away from that line in accordance with the well established principles of wave interference. If the

conflicting forces are in resonance, the nodal lines will strengthen. If the interference is nonresonant, then the nodal lines will be destroyed.

IX. Radial Charts

This section of the charts is drawn to illustrate the symmetry of the radial spacing of highs, lows, and cols at 1230Z on December 7, 1950. I've used some of the same charts used in the circumferential section to show the radial relationships.

The lines that were drawn on these charts are used to identify the points we are dealing with and nothing else; therefore they are drawn a little thicker and with less care than the lines on the previous series of charts. These lines were not used to calculate the distances. The latitude and longitude of each usable high, low, and col was carefully determined and then entered in a Table (Figure 10). This information was used to calculate the great circle distances between the points used in the charts. These calculated values, expressed in angular numbers, are entered on the map, next to each point where the measurement applies. The radial numbers entered on the charts when multiplied by 1.875 will give the distance in actual degrees of latitude between any two points. The other numbers that are circled are used to identify the points being analyzed.

This set of charts emphasizes the radial spacing, and some significant circumferential spacing similar to the first set of charts.

Chart 26A

In this chart, we find that 9 ru is the LCD. The most significant feature is #82 at 45 ru (5X9) and #31 at 36.5 ru (4X9= 36). The great circle distance between #31 and #82 is shown by the dashed line and has a measure of 45.1 ru. Thus we see that #26, #31, and #82 form an isosceles triangle with the sides in the ratio of 5:5:4. Next, we find that #10 at 36.4 ru (4X9= 36), is also 63.5 ru (7X9 =63) from #82. Thus we see that #26, #10, and #82 make another triangle with sides in the ratio of 4:5:7. Next, we have #13 (an obscure point) at 27 ru (3X9). Lastly, we have #80 at 45.3 ru and #49 at 17.9 ru, both of which are close multiples of 9.

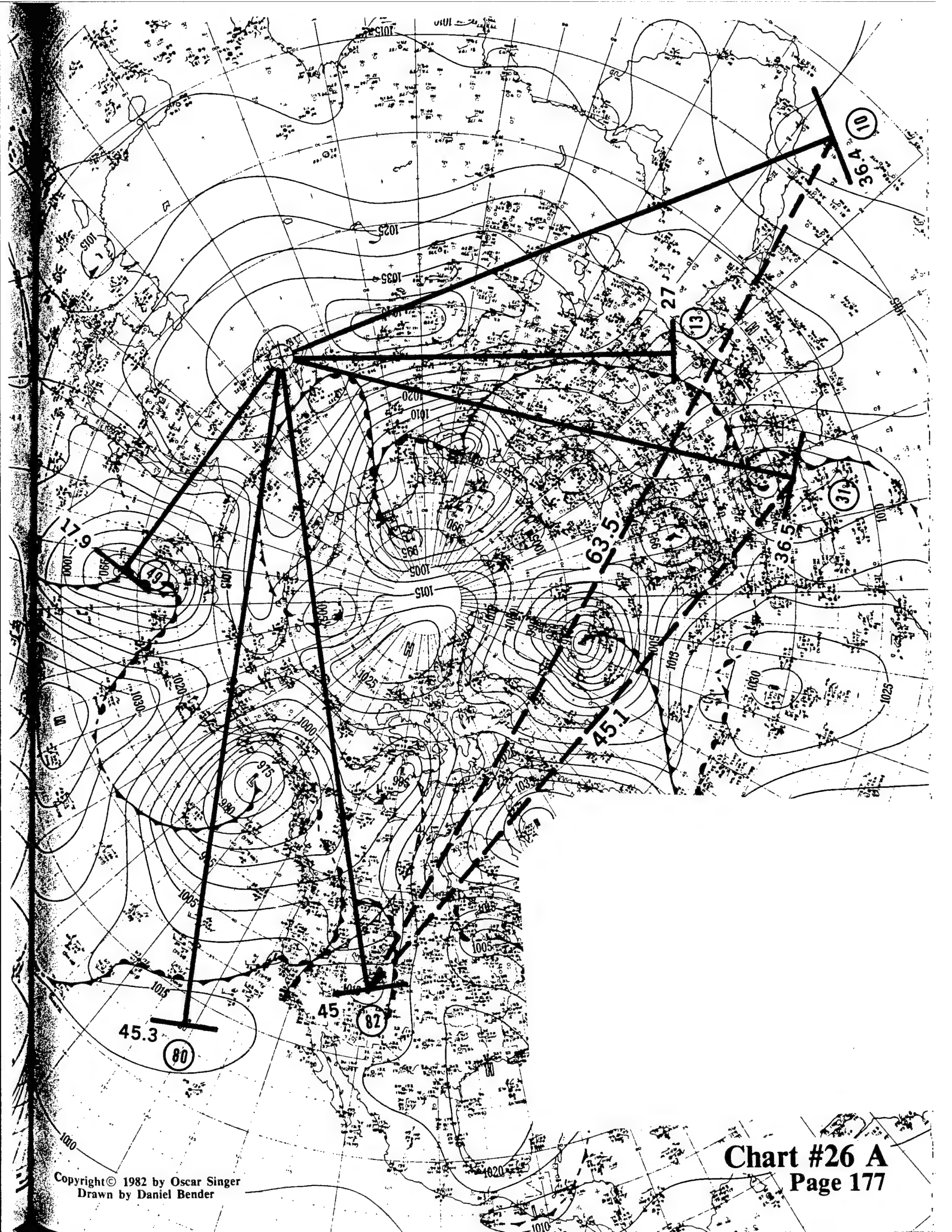


Chart #26 A

Drawn by Daniel Bender

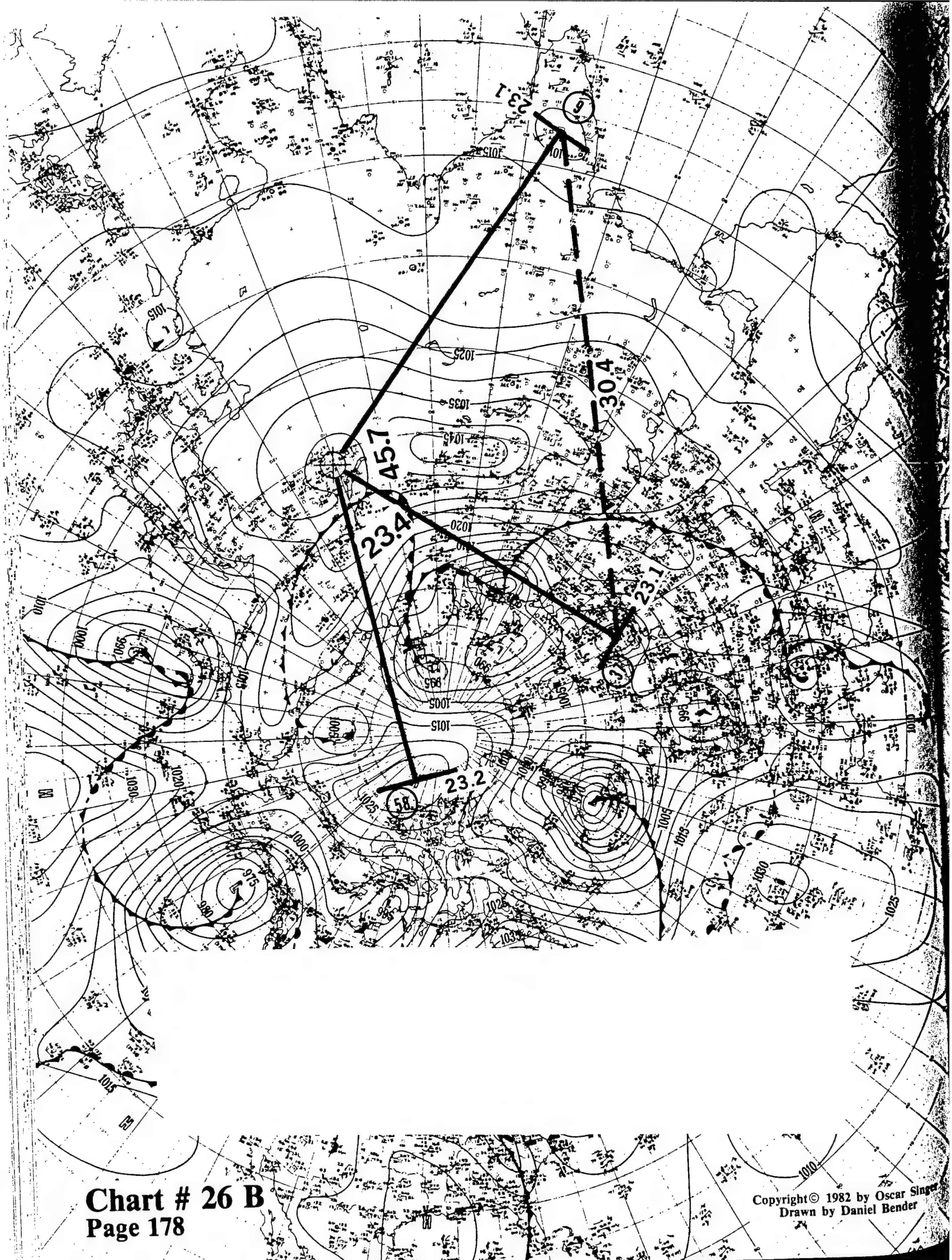


Chart # 26 B
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Chart 26B

#58 is 23.2 ru and #37 is 23.1 ru from #26. The angle formed by their rays is 23.4 cu. Similarly, the angle formed by the rays of #6 and #37 is 45.7 cu (2 x 23.1 = 46). One last touch, the great circle distance between #6 and #37 is 30.4 ru (4 x 7.7 = 30.8); and since 23.1 ru equals 3 x 7.7 exactly, we have an isosceles triangle with the sides in the ratio of 3:3:4.

Chart 26C

The LCD for this map is approximately 15 ru (or 7.5 ru if you prefer). The strongest feature is #80 (45.3 ru) and #60 (30.3 ru), with their rays to the center separated by an angle of 29.7 cu. The great circle distance between #26 and #60 is 30.3 ru (4x7.5 = 30); between #60 and #80 is 37.5 ru (5x7.5); and between #80 and #26 is 45.3 ru (6x7.5=45). This gives us a triangle with sides in the ratio of 4:5:6. #3 (15 ru) (drawn with a dashed line since it is obscure) is almost in a straight line with #103 (59.7 ru), for an approximate ratio of 4:1. #76 (30.1 ru), #82 (45 ru), and #103 (59.7 ru) are close to making a straight line, if you join their centers.

Chart 26D

The LCD of 16 ru gives a nice pattern with regularity along two separate axes. One axis consists of #4, #26, #45, #69, and #91. The other axis consists of #21, #26, #15, and#l2.

Or you may want to look at the pattern as consisting of a ring with #26 as the center, and points #4, #15, #45, and #21 on the circumference--with a second partial ring farther out at double the radius (nearly 32 ru) formed by #12 (31.8 ru) and #69 (32.1 ru)--followed by a fragmentary third ring with #91 at a radius of 47.6 ru (3x16=48).

Chart 26E

The most straightforward feature on this map is #20 (13.3 ru) on a nearly straight line through #26 and #36 (26.6 ru). The rest of the points can be considered as part of three separate waves or ringlets. The first wave front is, #77 (26.5 ru) and #36 (26.6 >ru) in the ratio of about 2:1, with the LCD of 13.3 ru. The second wave front consists of #84 (39.6 ru), #86 (38.9 ru), and #67 (38.9 ru) which are in the ratio of about 3:1 to the LCD. The third wave consists of #99 (51.8 ru) and #90 (52.3 ru) which are approximately in the ratio of 4:1.

Chart 26F

The LCD on this map is about 6.2 ru. #19 (6.2 ru) is opposite #22 (12.5 ru) in the ratio of 1:2. #22 (12.5 ru) is opposite to #30 (37.7 ru) in the ratio of 1:3. #55 (18.9 ru) is opposite to #5 (18.7 ru) in the ratio of 1:1. #22, #26, #28, #33, #30, and #61 seem to be along a single axis and all have an LCD close to 6.2 ru. We can also take note of the ring or wavefront formed by #5, #28, and #55.

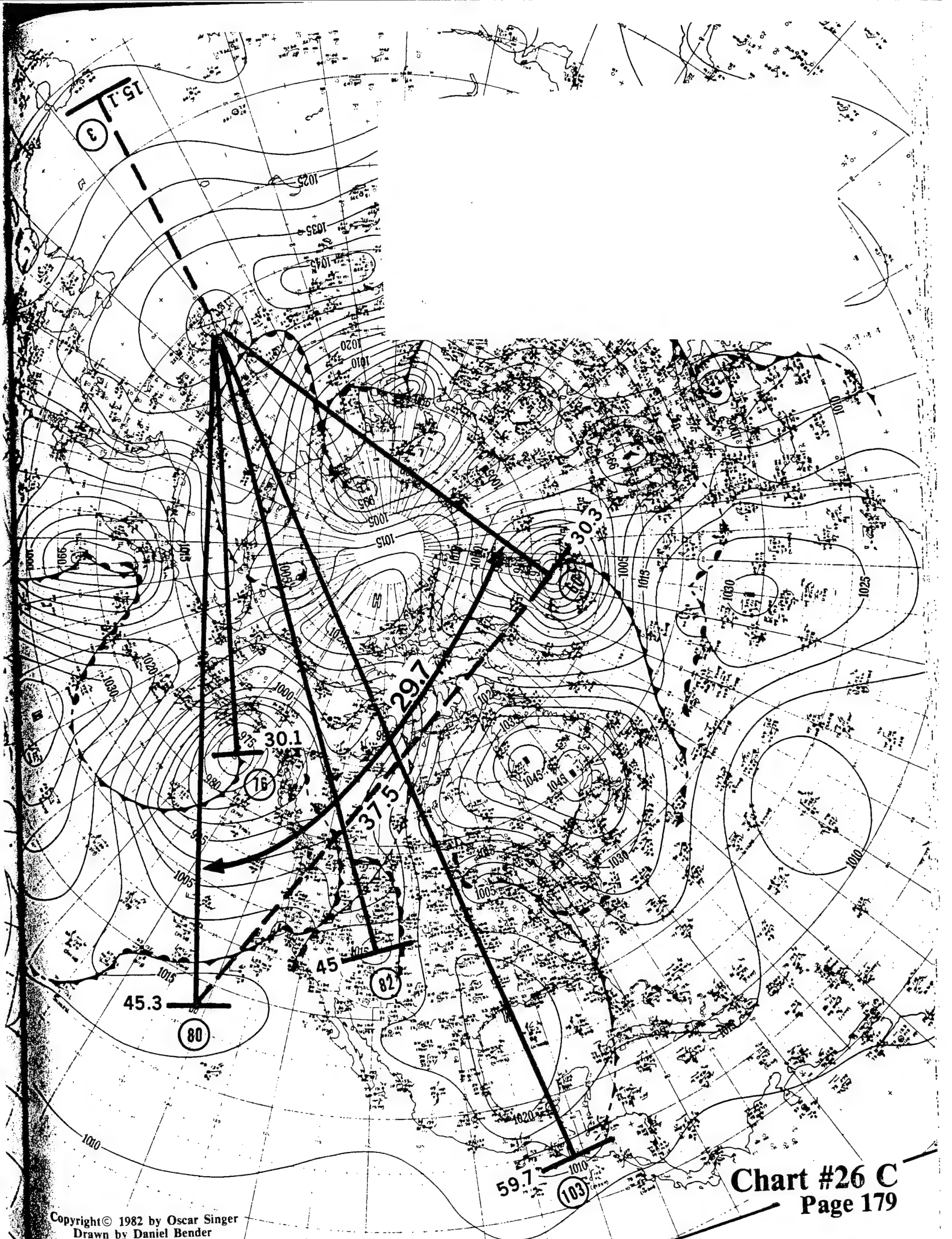


Chart #26 C

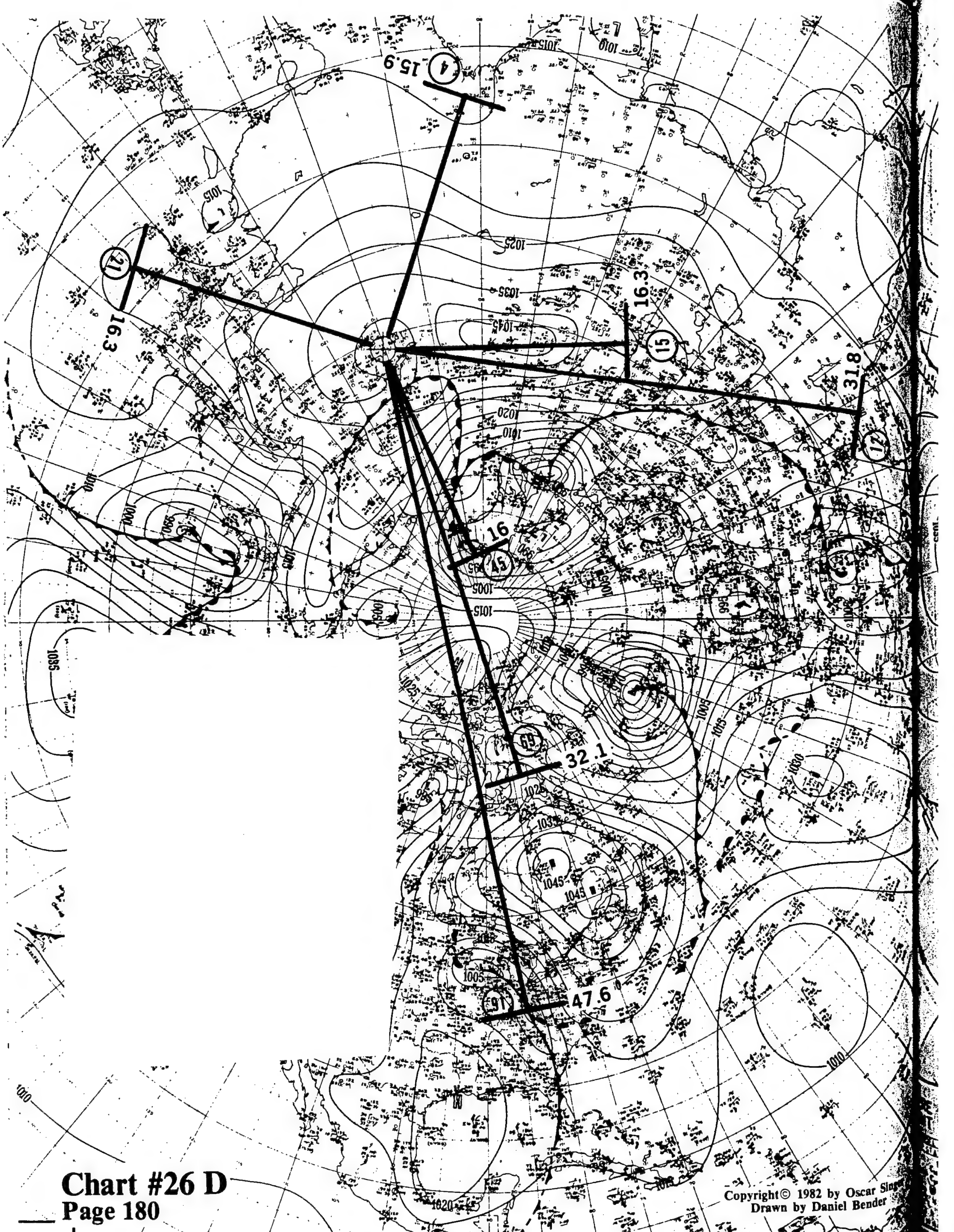
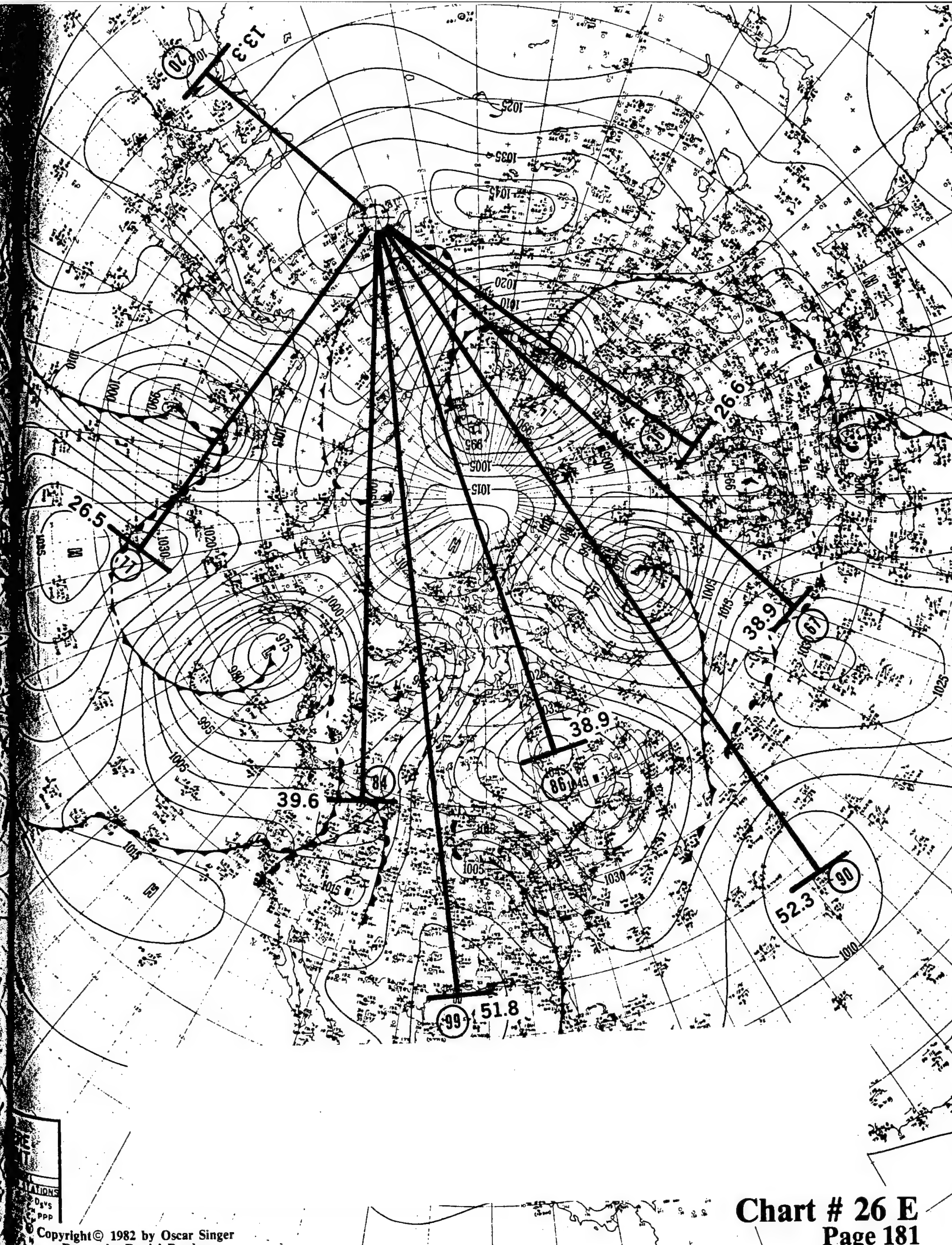

15.9
16.3
21
16.3
15
31.8
17
16
32.1
47.6
1025
1035
1045
1020
1010
1005
1015
1030
1045
1045
1005
1010
1085

Chart #26 D



Drawn by Daniel Bender

Chart # 26 E

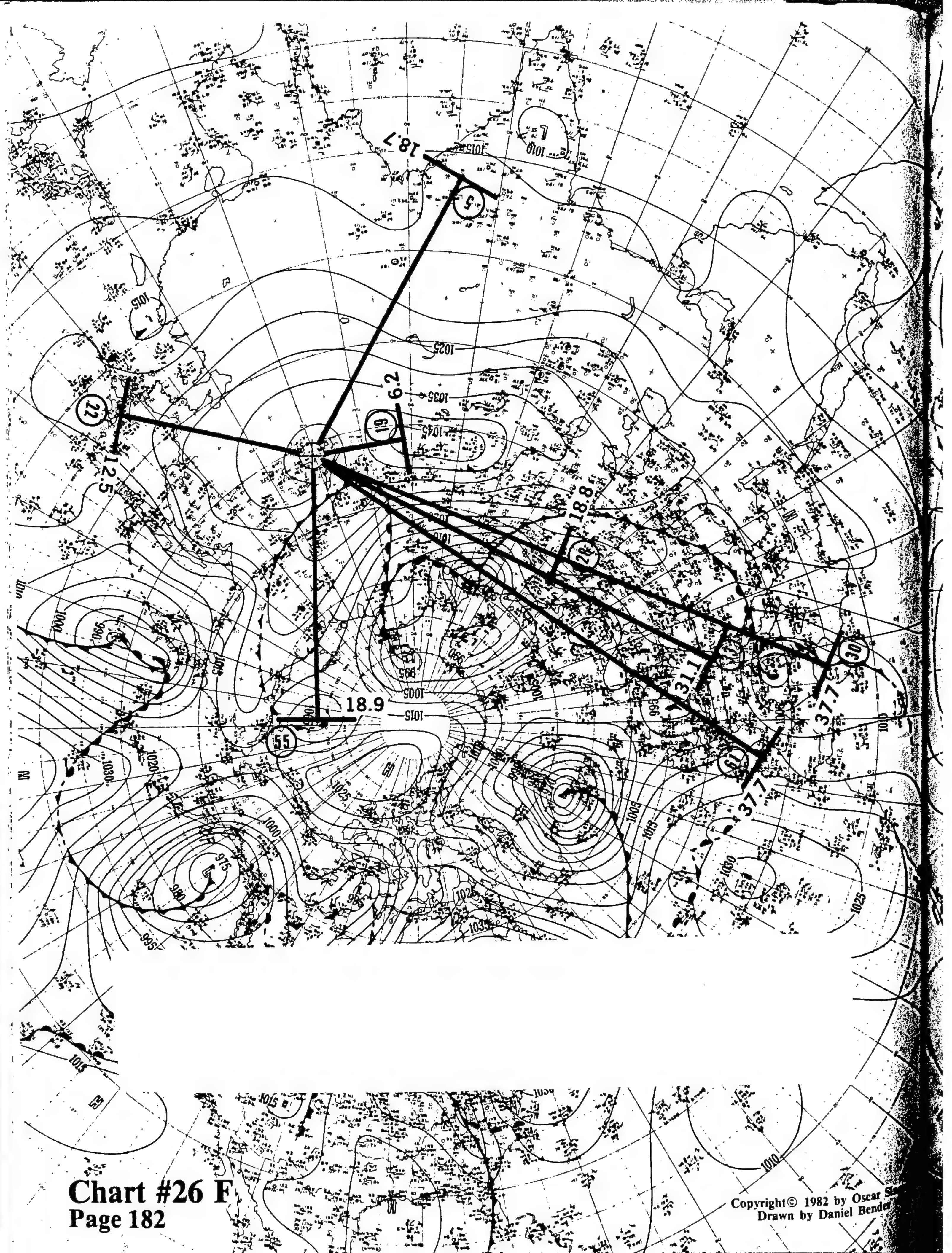


Chart #26 F
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Chart 45A

This melody in the symphony of weather patterns begins with an LCD of 12.2 ru at #54. #77 (24.5 ru) and #87 (24.3 ru) which form two sides of a triangle with 32.5 ru between these two points completing the third side of a triangle with the legs in a ratio of 3:3:4. In a similar manner, the triangle formed by #45, #87, and #54 has sides in the ratio of 2:2:1. Lastly, we have #80 and #90, both at 36.8 ru, spaced in a relatively symmetrical manner with respect to #77 and #87.

Chart 45B

First we note that #58 and #55 at 8.1 ru, and #42 at 8 ru, are three well-defined points that are all close to being equal. Doubling this distance outwards from #45, gives four more points: #26 (16 ru), #17 (15.9 ru), #75 (16.4ru), and #69 (16.3 ru). That is not the end of it yet; #82 (32.3 ru) and #91 (32.2 ru) are the third wavelet. Last but not least, we have the fourth wave represented by #97 at 40.7 ru (5x8.1=40.5).

Chart 45C

The clear feature of this one is #60 at 15.1 ru, counterbalanced at approximately double the distance, by #21 at 29.8 ru. Likewise, #4 is also at 29.8 ru, and is counterbalanced by #92 at 30.7 ru. Lastly, #103 is 45.2 ru (3 x 15.1 =45.3).

One additional fact to note at this time is the formation of an "X" type of pattern by the four points: #4, #103, #21, and #60. The author states this "X" formation occurs often.

Chart 45D

In this chart we have an LCD of 11.5 ru. #74 (23 ru) and #86 (23.1 ru) are counterbalanced by #6 at 34.4 ru (3x11.5=34.5). #14 and #101 are obscure and may be questionable. This chart shows the "X" pattern of Chart #45 C changing to what looks like a "K" pattern.

Chart 45E

In this simple one we have #20 at 28.7 ru counterbalanced by #63 at 28.6 ru, with the obscure #25 acting as the LCD of 14.2 ru.

Chart 45F

Here we see another "K" formation as in Chart #45 D. #50 and #34 are both well-defined centers, while the two points in the legs' of the "K" are comparatively obscure.

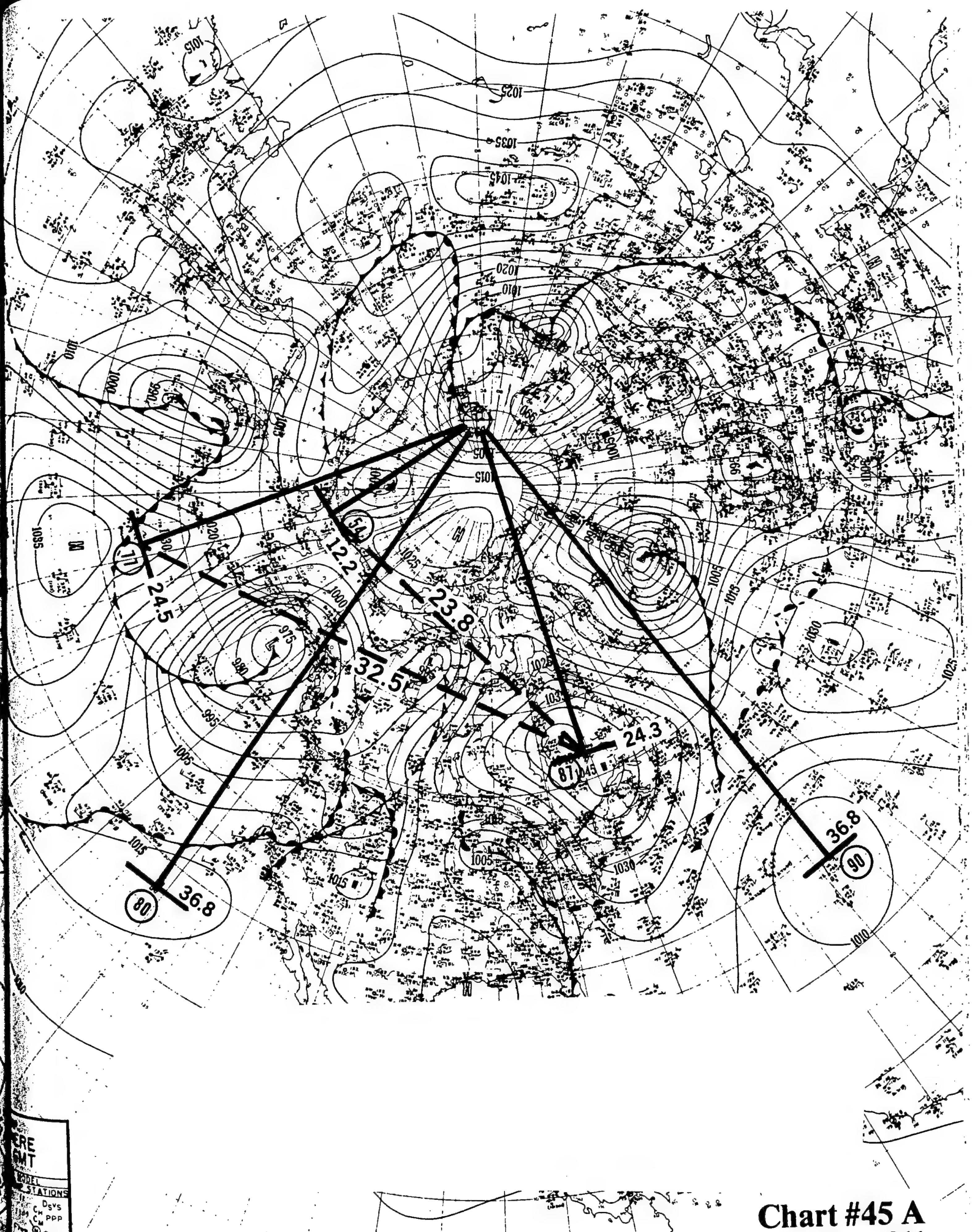


Chart #45 A

Drawn by Daniel Bender

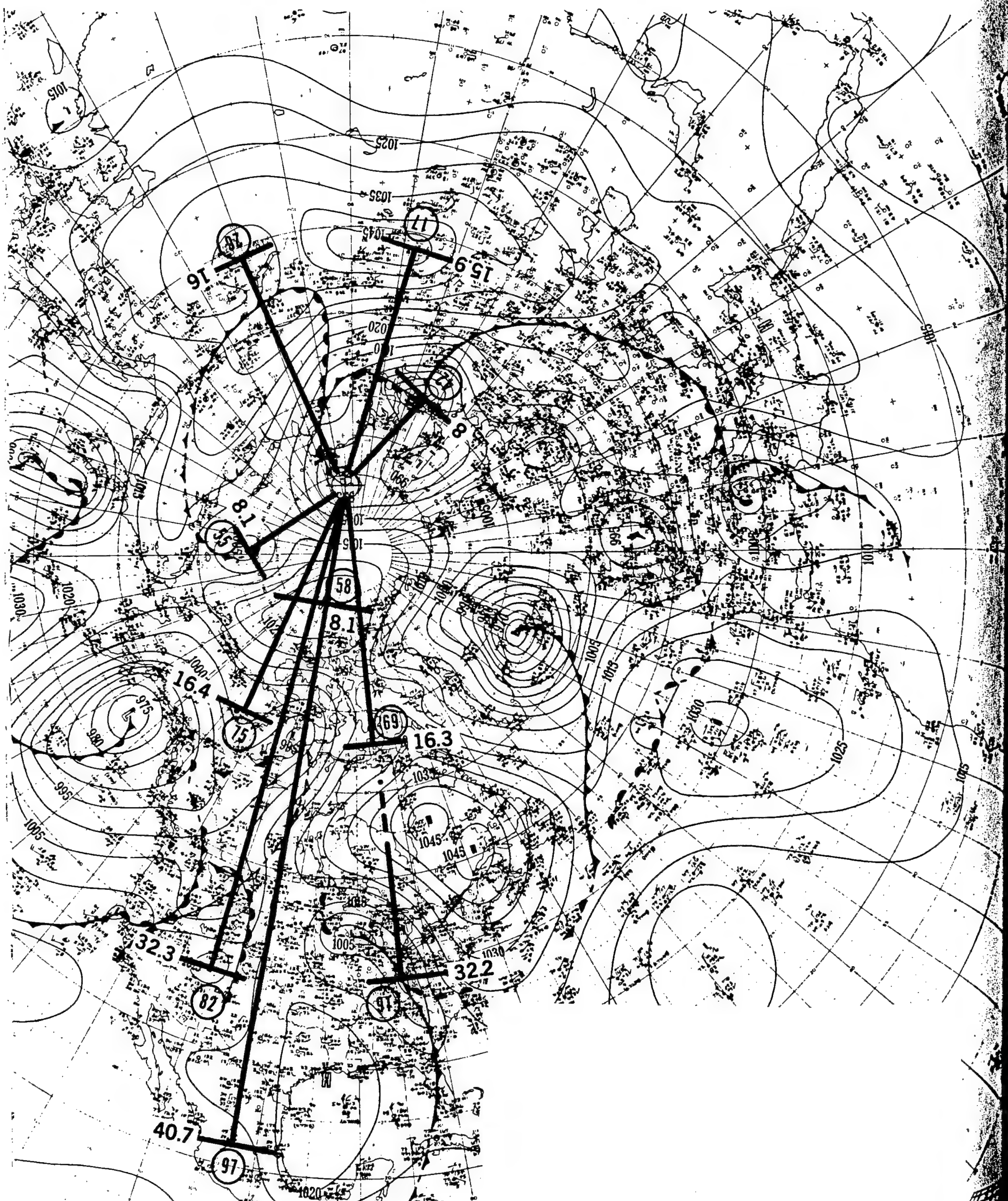
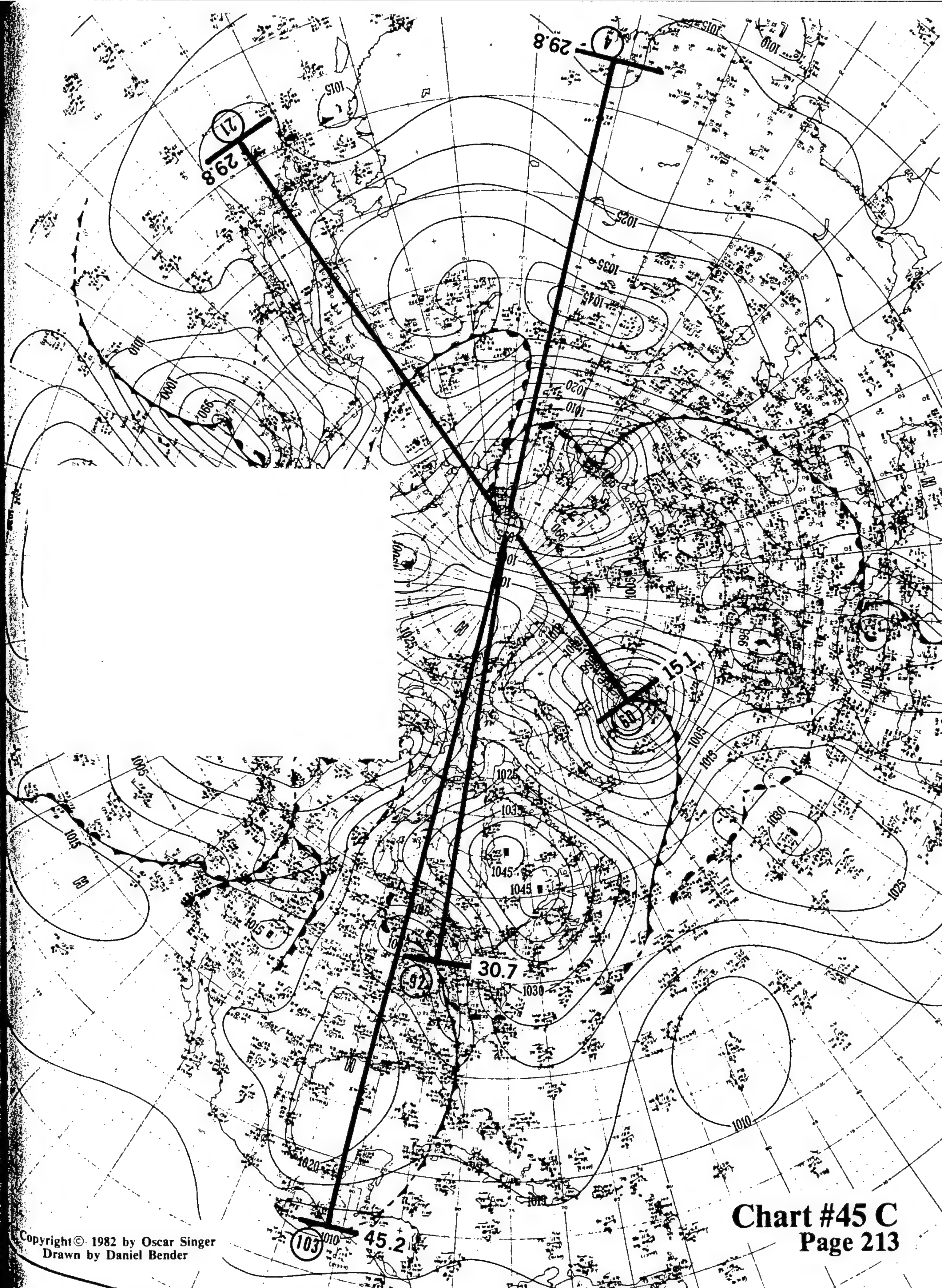


Chart #45 B
Page 212

Drawn by Daniel Bender



Drawn by Daniel Bender

Chart #45 C

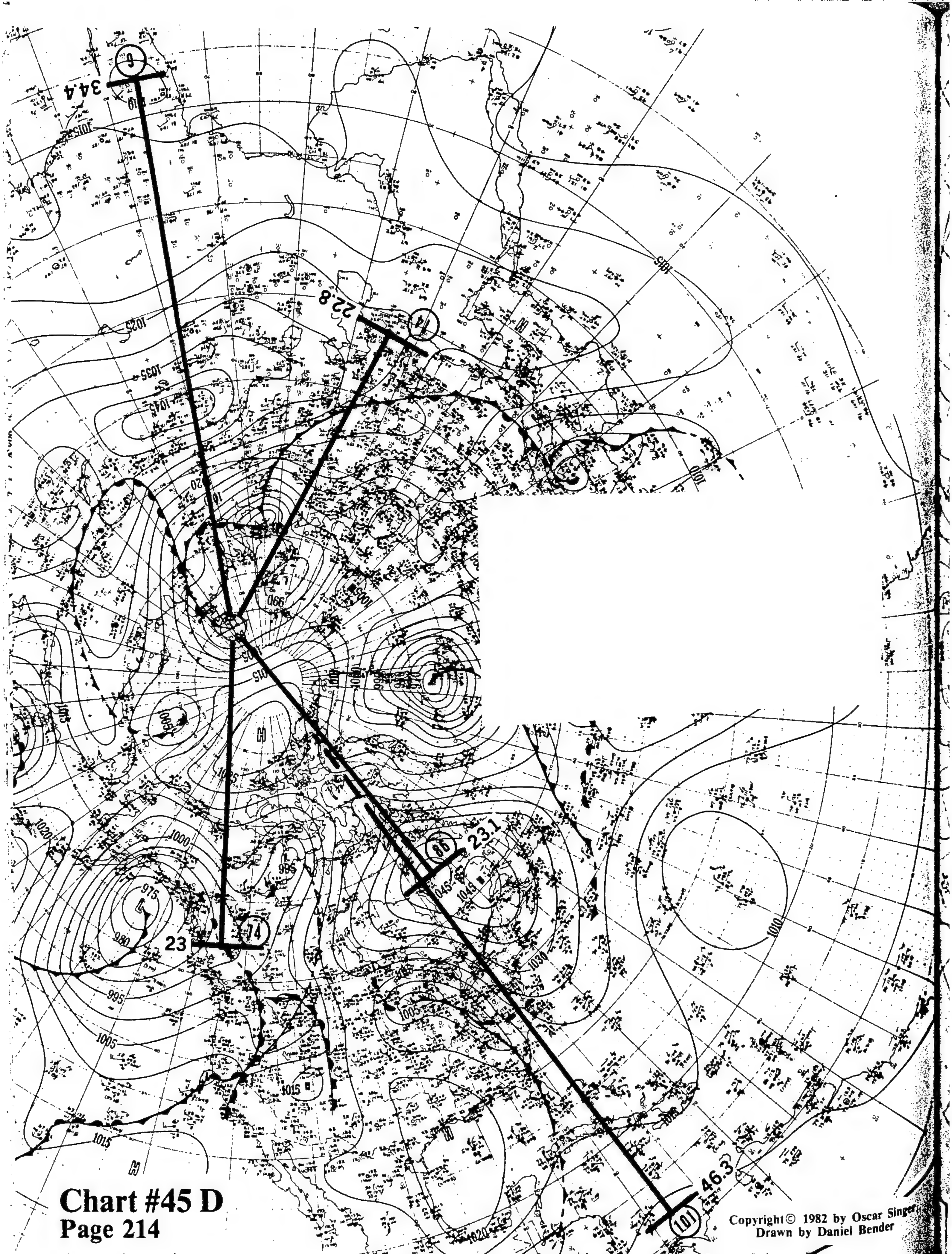


Chart #45 D
Page 214

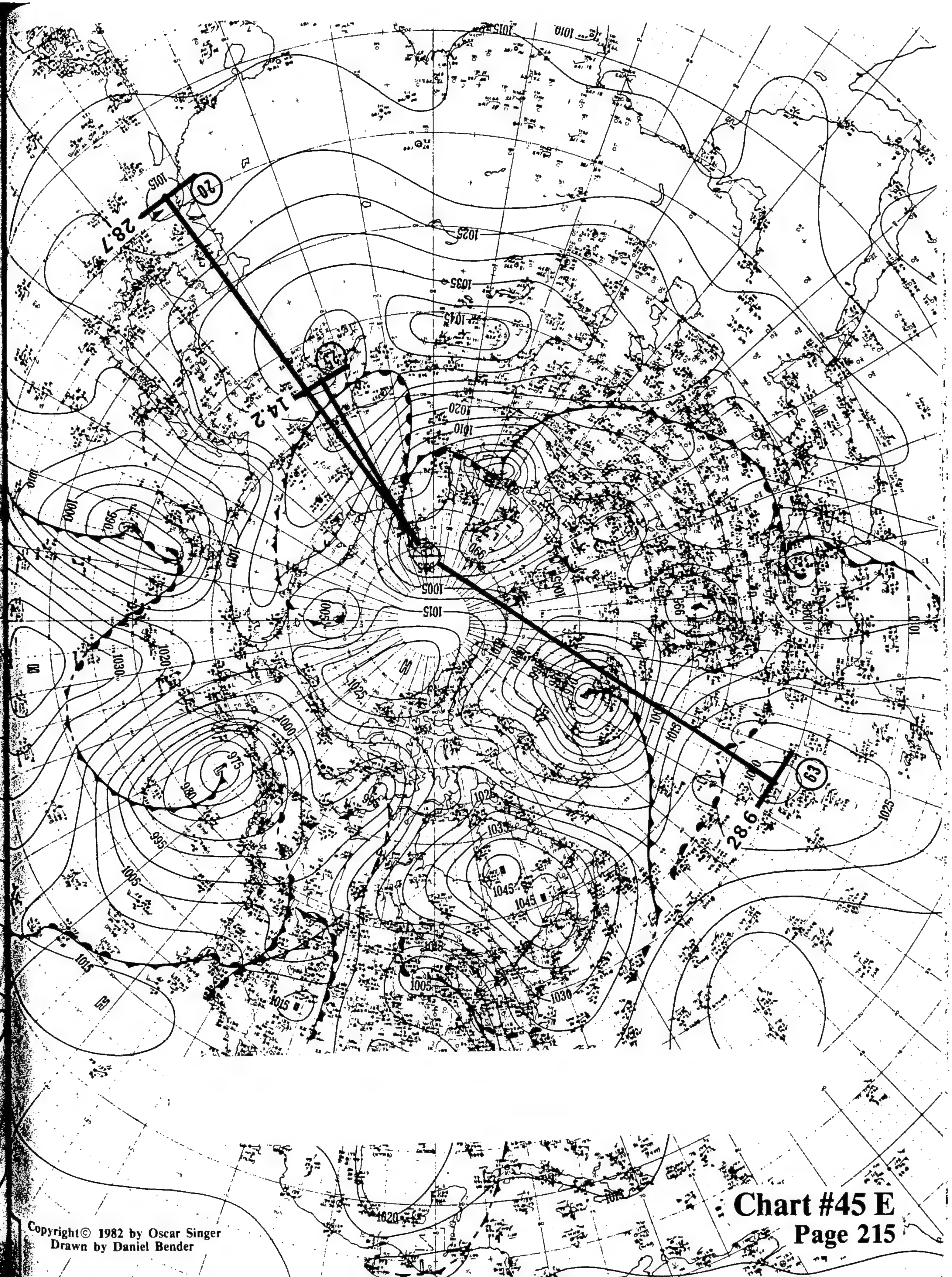


Chart #45 E

Drawn by Daniel Bender

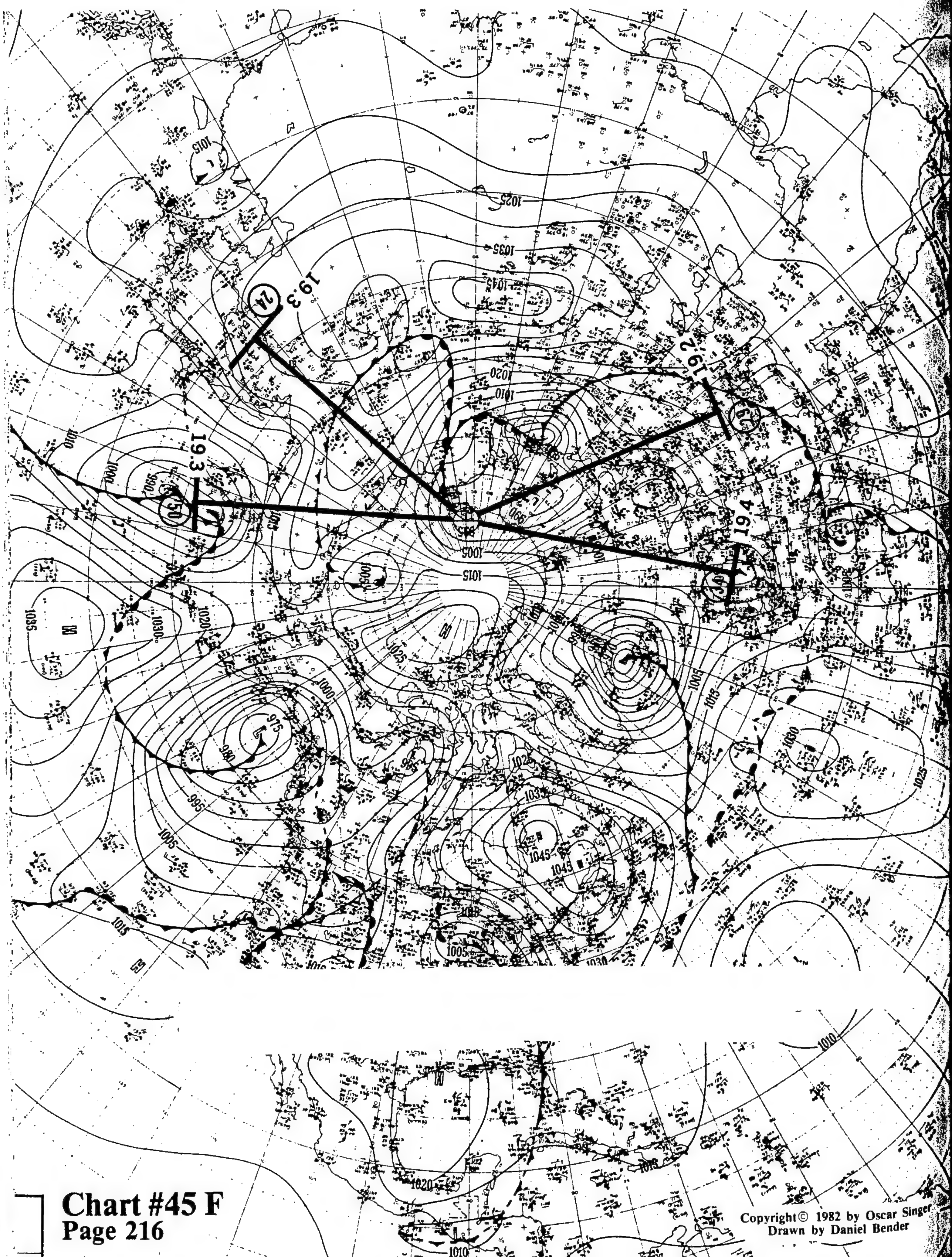


Chart #45 F
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Chart 55A

First we have #77 (16.8 ru) in a nearly straight line with #32 (33.4 ru). This pair looks good together, but they don't really belong in this pattern directly (they have been added since they are close to the value of the others).

#27 (16.4 ru) is balanced by #74 (16.2 ru), while #45 at 8.1 ru almost doubles to 16 ru at #42. These three pairs are the highlights, while the rest of the points are all divisible by an LCD of 8 to 8.2 ru.

One other feature that should not be overlooked is the existence of two fairly definite rings: the first at approximately 17 ru includes #27, #42, #39, #74, and #77; the second ring at double the distance of approximately 32 ru, includes #32, #61, #63, #99, and #96.

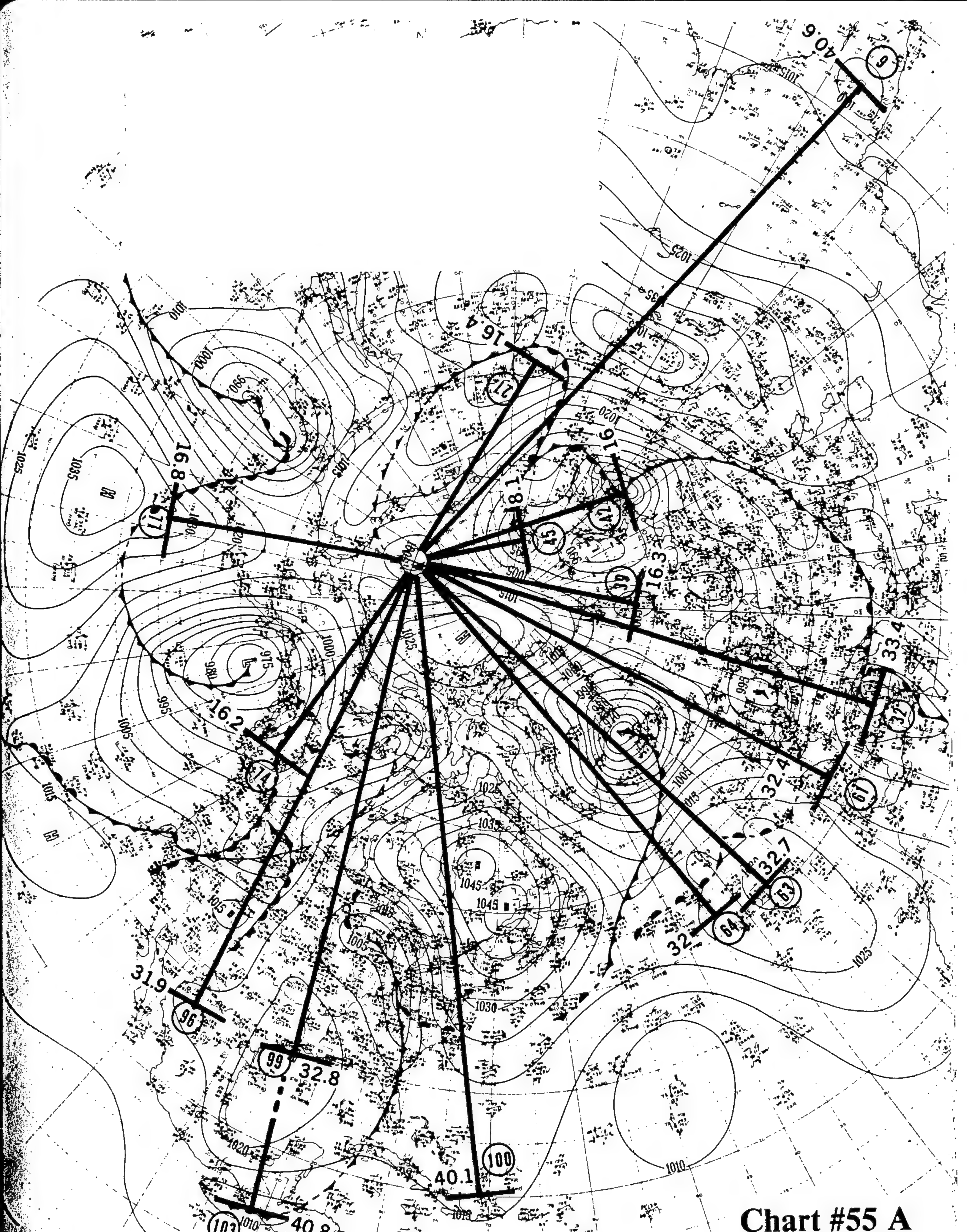
Chart 55B

The powerful feature of this pattern is #20 at 29.1 ru, almost diametrically opposite to #91 also at 29.1 ru; while at the same time #91 is 21.7 ru from #80, which is also at 29.2 ru. The LCD for the distances in the four points involved is approximately 7.25 ru.

Not quite as good, but interesting nevertheless, we find #65 at 28.9 ru and a distance of 20.6 ru from #91. Lastly, in order to make a "flying kite", the dismal point of #101 at 43.5 ru (6x7.25) and its auxiliary distances of 27.7 and 28 ru were also added.

Chart 55C

There are many fine symmetry features in this chart based on an LCD of 13 ru. First, we have the ring formed by the gang of four: #40 (13.2 ru), #59 (13 ru), #72 (12.9 ru), and #76 (13.3 ru). Second, we have a ring at approximately double the distance, which includes #15, #34, #93, #82, and #79. Third, #58 is exactly half the distance of #59; likewise, #72 is half the distance of #93; similarly #40 is one-third the distance of #9; and similarly #15 is two-thirds the distance of #7. Fourth, to seal this impressive display of regularity, we find that the angle between #76 and #59 adds up to 52.1 cu (4 x 13 = 52); and the ray formed by #72 splits this angle into approximately two equal parts.



Drawn by Daniel Bender

Chart #55 A

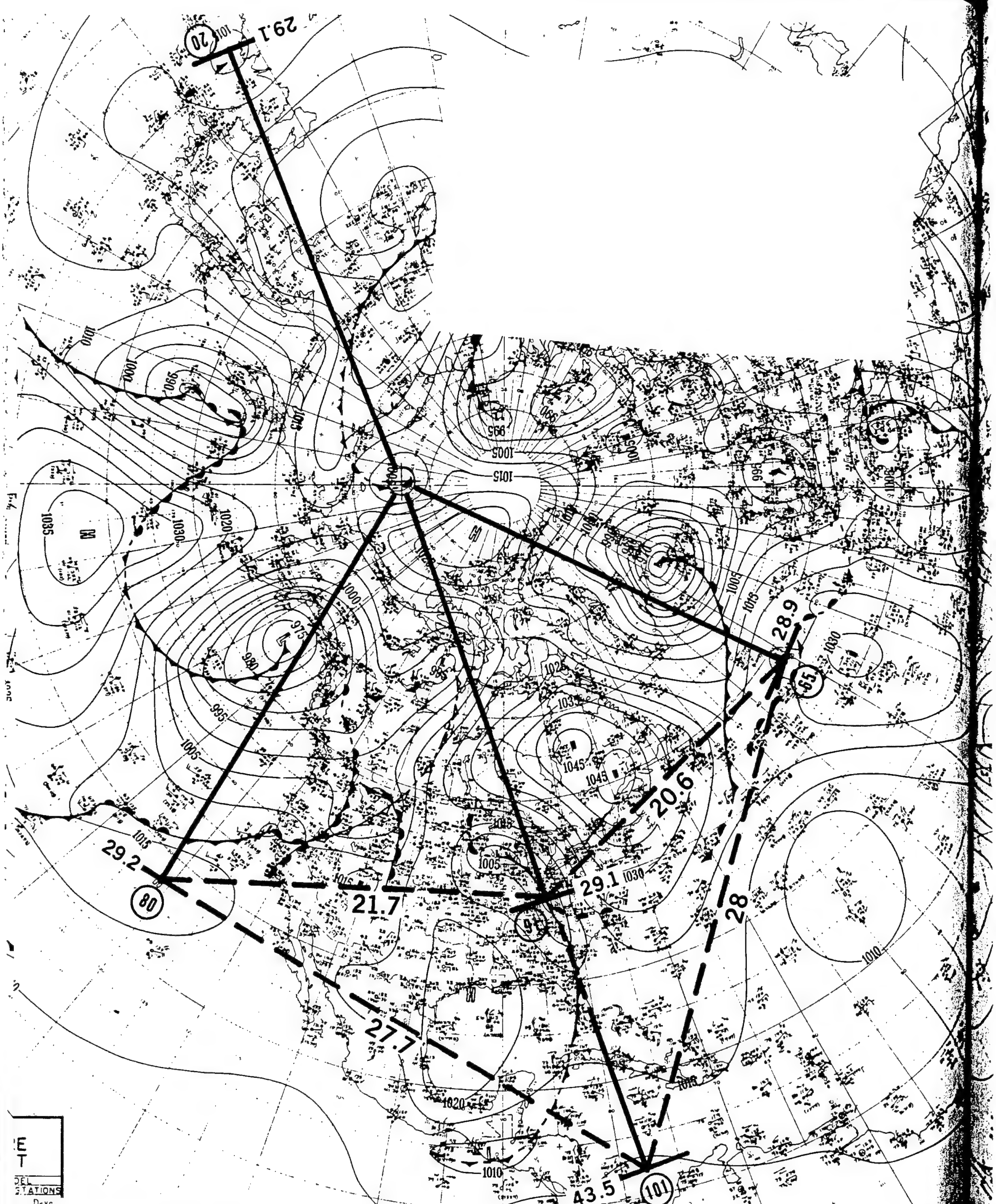


Chart #55 B
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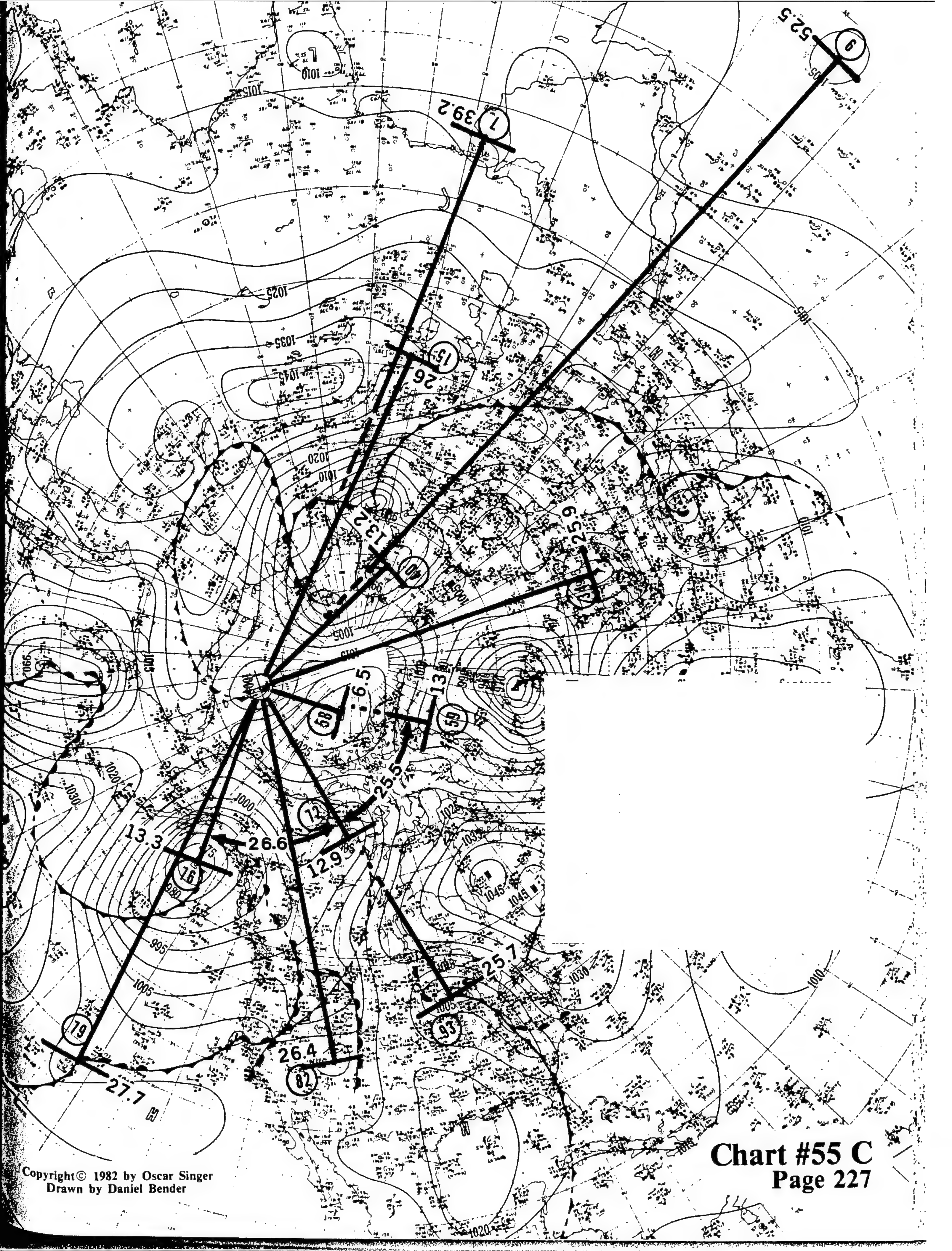

Chart #55 C
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Chart 58A

There are four striking features on this chart. First, #82 at 24.2 ru is in a nearly straight line with #17 at 24 ru, while the LCD of 8.1 ru for #45 hugs this line very closely; second, we have a substantial ring involving seven points with about 24 ru which is equal to 45 degrees; third, there is a secondary ringlet involving #90 and #30 at approximately 32 ru; fourth and last, we have 24.4 cu for the angle between #81 and #91--and 50 cu (2x24.4=48.8) between #81 and #48.

Chart 58B

This one is shining star! It is useful to expand the two-axis concept with this chart. If we consider the direction from #58 to #38 to be on the positive axis for X, then #79 would lie near the negative axis for X, while #22 would automatically be near the Y-axis from #58 as the origin. Looking at this classic pattern, we see two "V" type patterns joining together to form an "X" type pattern. Looking again, we can see two "K" type patterns back to back. We can see that the "K", the "X", and the "V" patterns are actually vestigial portions of this two-axis array.
By inspection, we see essentially two rings--one at approximately 15 ru, and the other at 30 ru.

Chart 58C

Here we have the two-axis pattern with a "V" type spray in the general direction of the + Y-axis, which may be considered as lying along the ray to #5. The LCD is approximately 13 ru. We find that #63 is about twice as far out as #60; that #5 is approximately 3 times as far as #43; and that #15 is two-thirds of the distance of #7. When you take a position at the center of #58 you will see that all the shorter rays are approximately the same angle to the left of the nearest larger ray.

Chart 58D

Here we have another rake, with a plus and minus X-axis only, and with a "V" type spray in one branch, of the axis. We see once again, the almost perfect counter-weight of #20 at 34.7 ru, against #100 at 34.9 ru. We find that the LCD of #53 at 11.7 ru (although all the points are operating on an LCD that is closer to 11.6 ru).

Chart 58E

Another two-axis pattern with a small spray on the X-axis and a wider "V" type spray on the Y-axis. We find an LCD at 9.35 ru, which is the average of 9.2 and 9.5 ru of #54 and #72. With the modified LCD, we get a nice ring at about 18.7 ru.

Chart 58F

This scatter pattern was developed with an LCD of 10 ru (#70).

Chart 58G

This is a simple pattern, but cannot be considered to be first class, since we use #73, which is an obscure point.

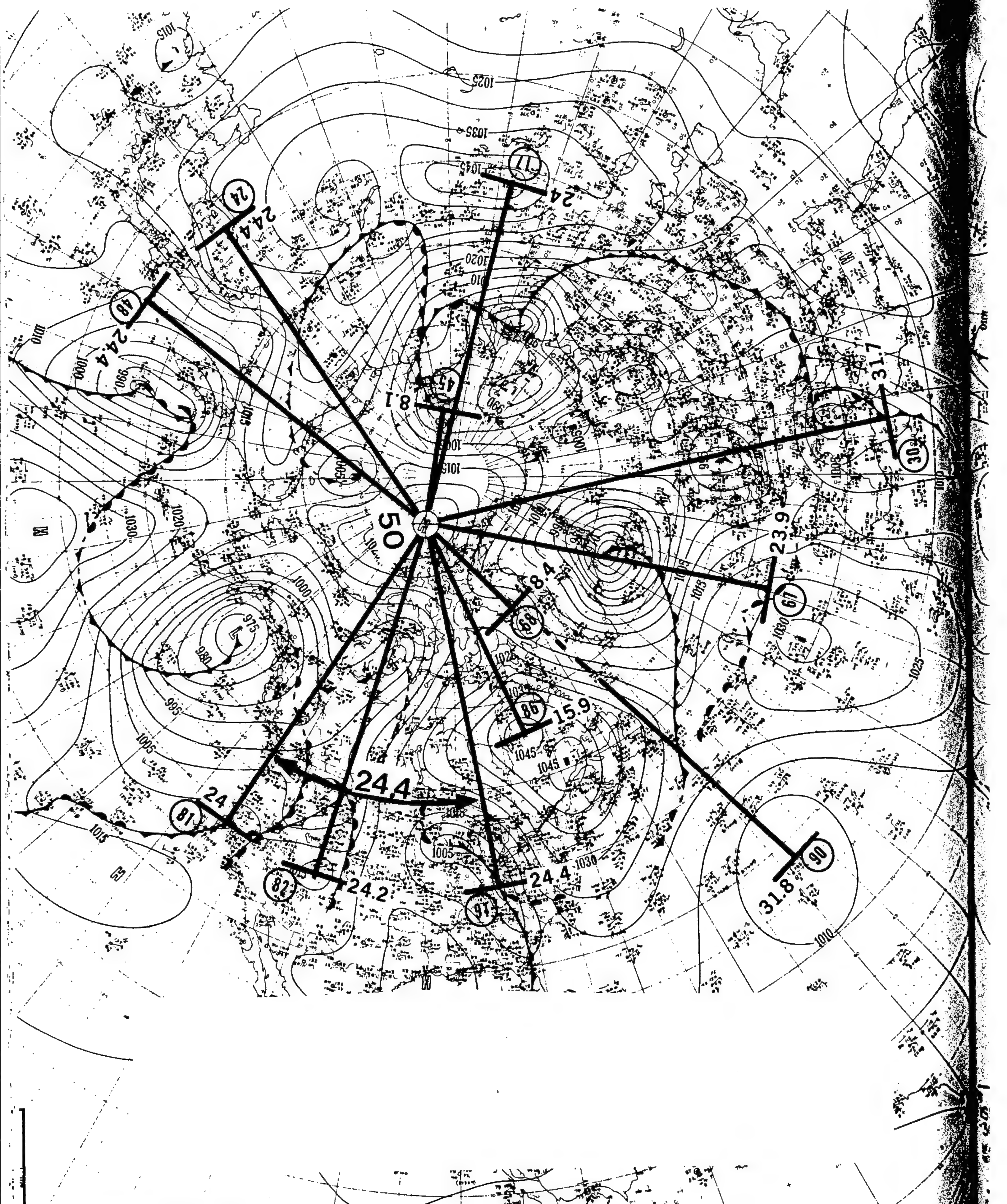
50
24.4
24.4
24
8.1
45
8.4
68
15.9
98
23.9
67
31.7
30
31.8
90
24.4
91
24.2
82
24
81
48
24.4
24
1045
1030
1025
1020
1015
1010
1005
1000
995
990
980
975

Chart #58 A

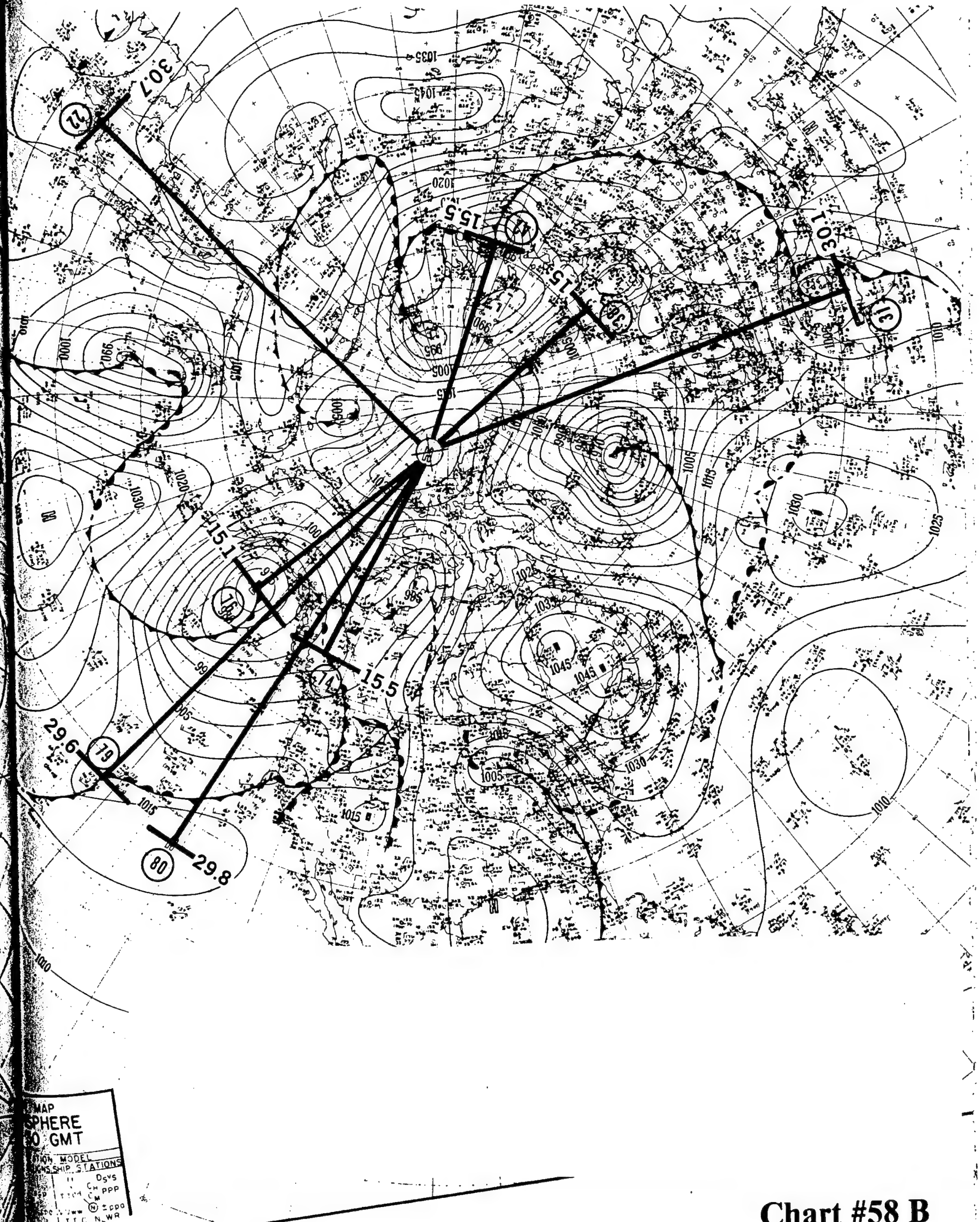

Chart #58 B

Drawn by Daniel Bender

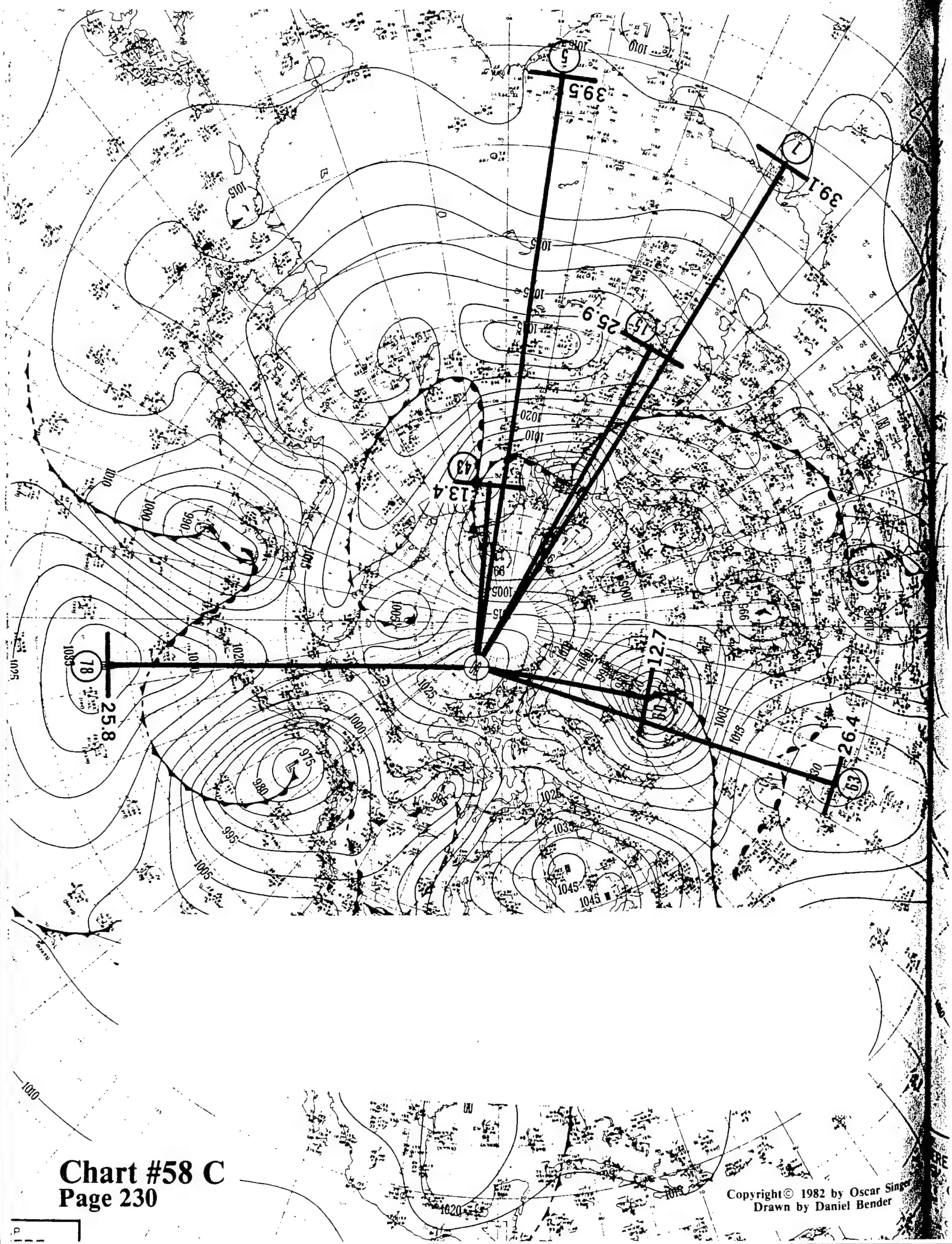

Chart #58 C
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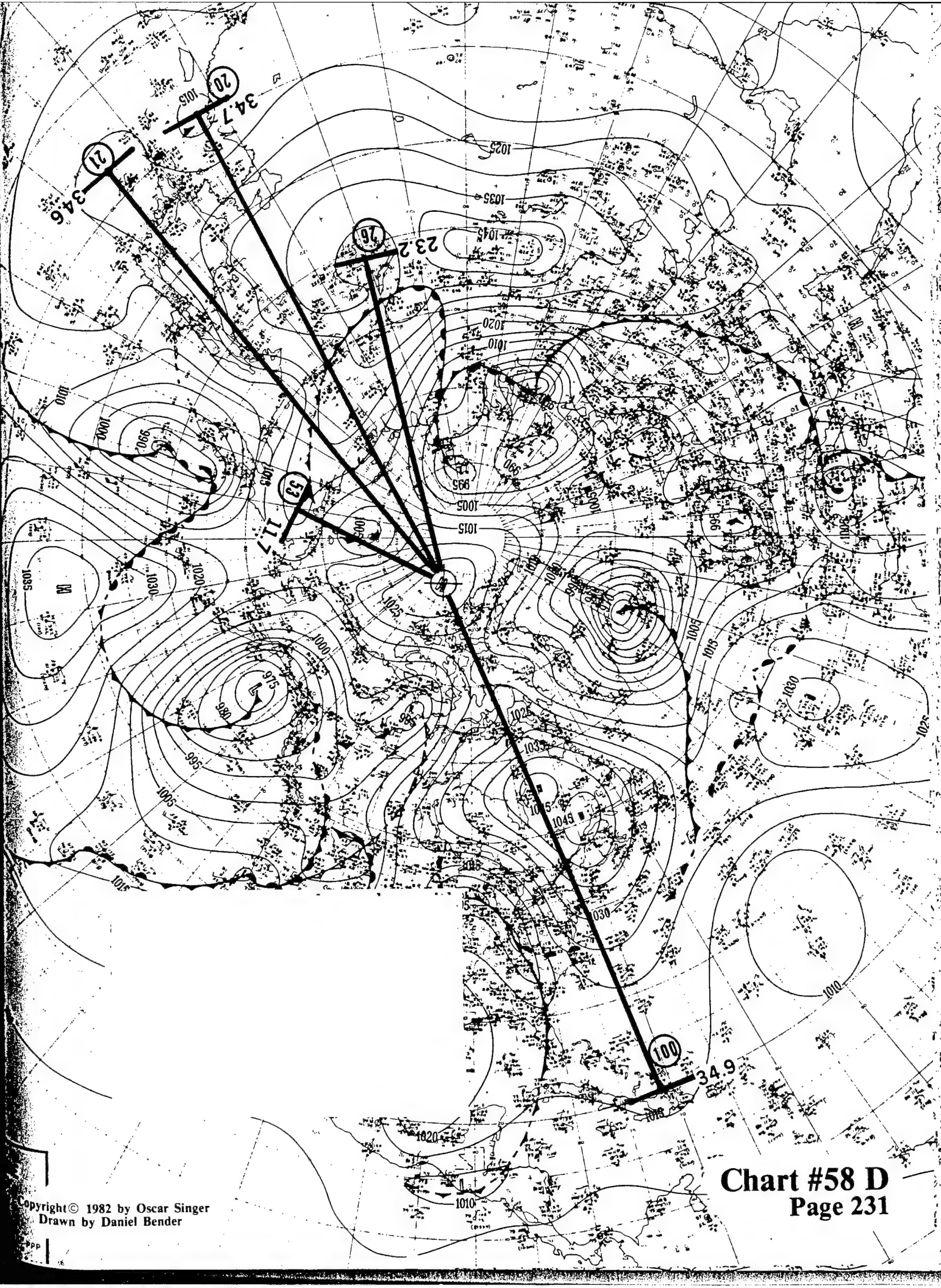

Chart #58 D
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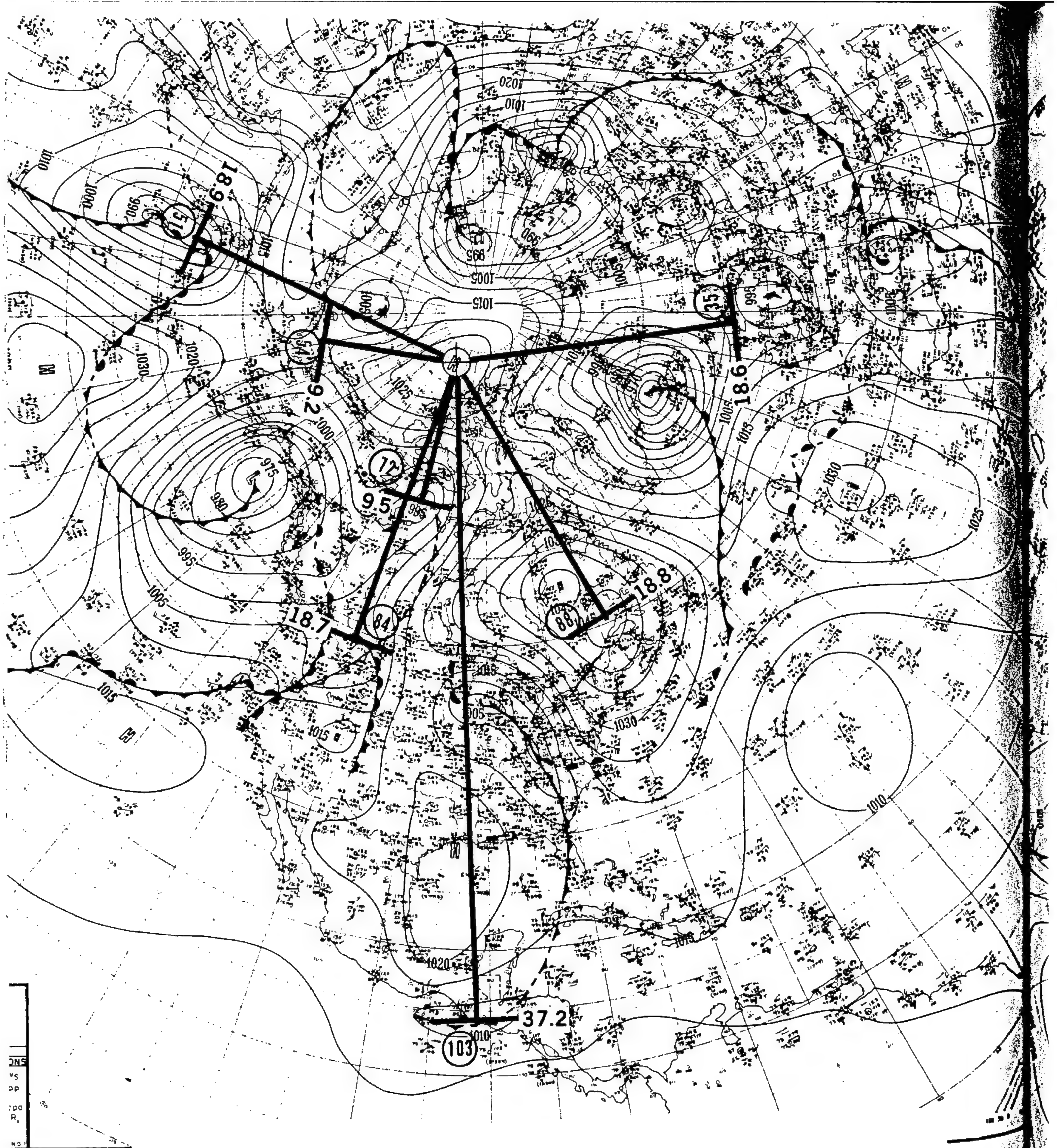

Chart #58 E
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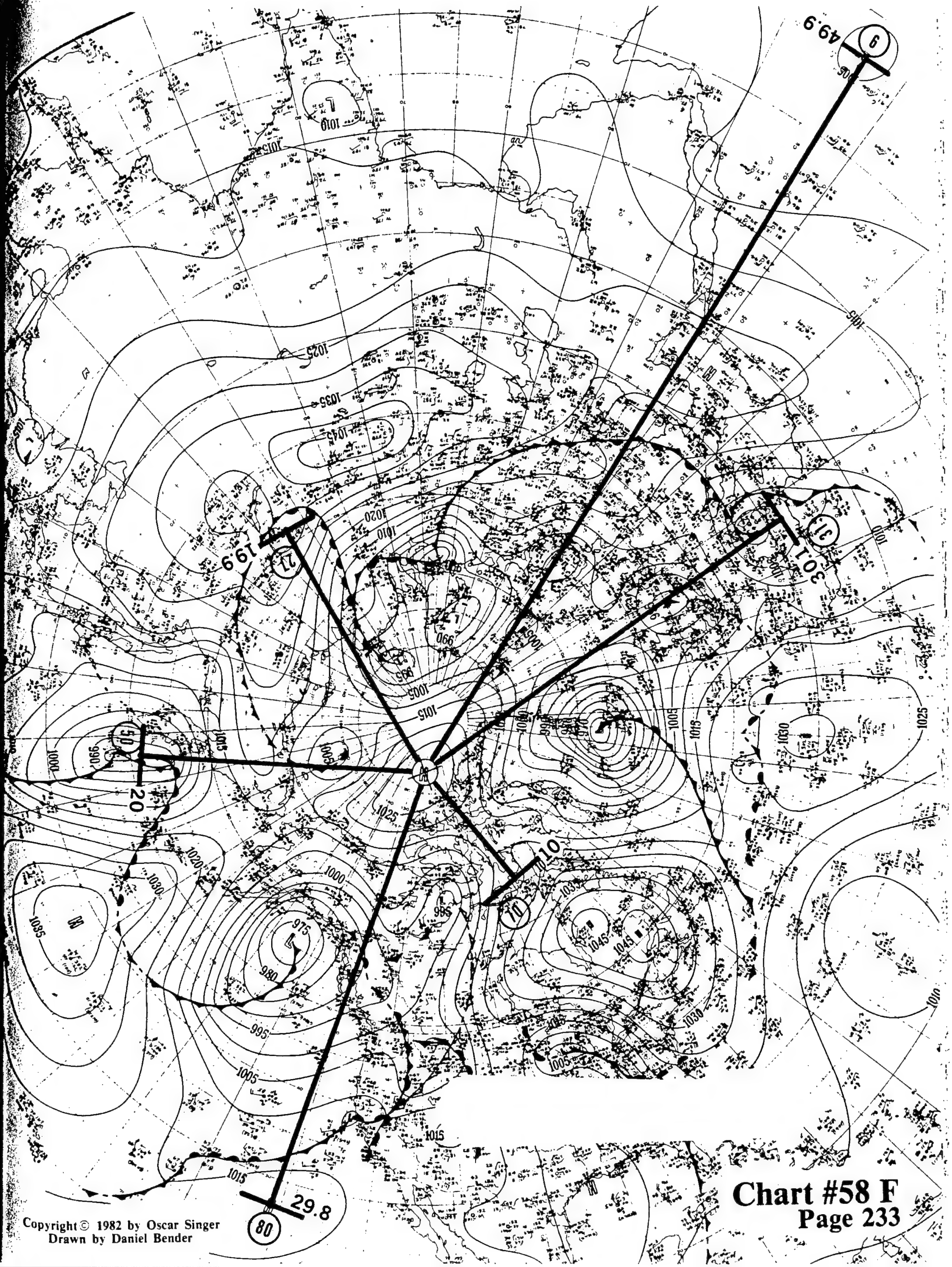
49.9
19.9
30.1
20
10
29.8
1025
1035
1045
1020
1010
1005
1015
1000
975
980
995
1045
1030

Chart #58 F

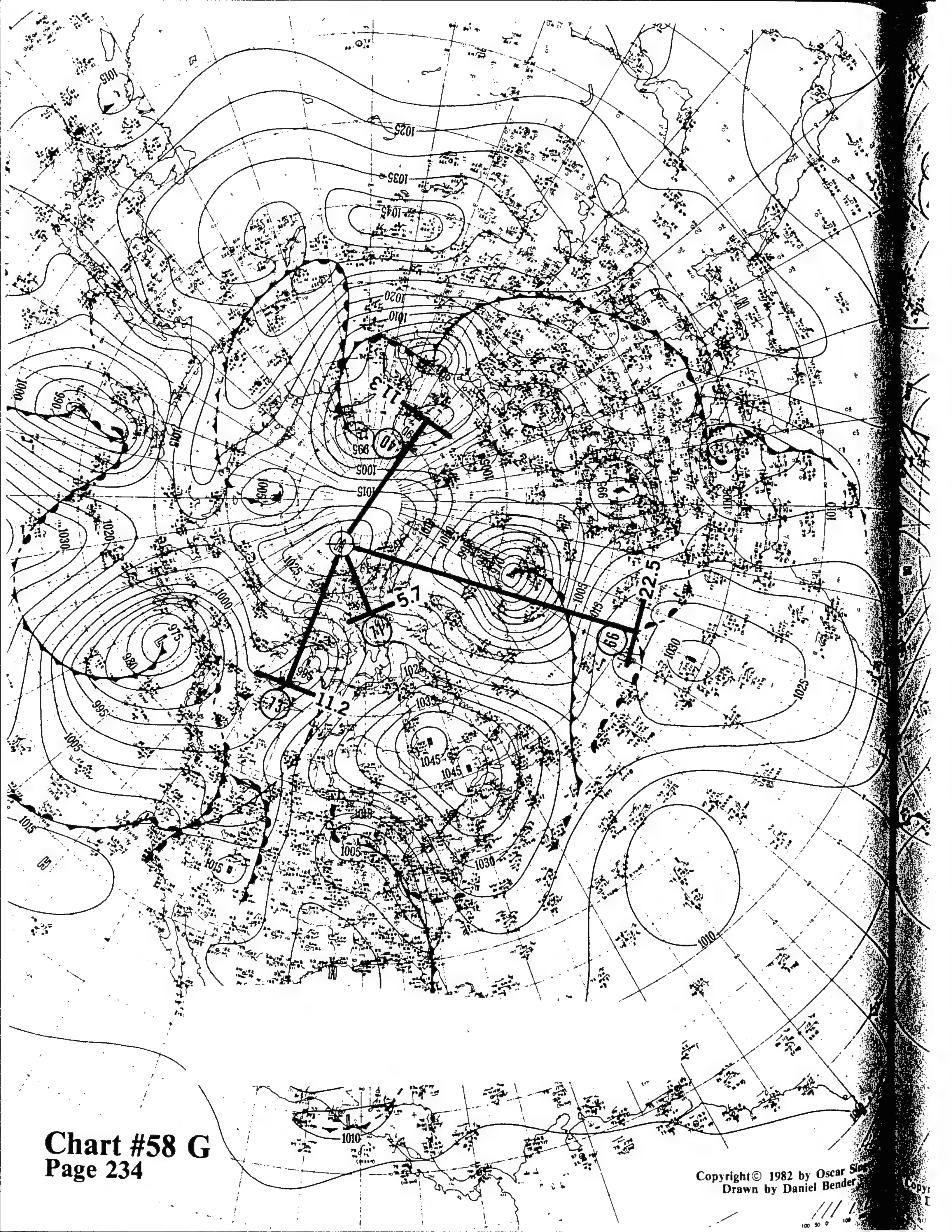

Chart #58 G

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X. Summer Chart Example

Two charts are included for a summer month. This was done for two reasons. To use a different day to show the relationships and to use the less dynamic summer months as opposed to all the previous winter examples.

Mr. Singer chose June 6, 1944. This is a significant day for meteorological historians, D-Day-the Normandy Invasion. The vortex selected, as the center point was the one associated with the weather affecting the invasion. A circumferential analysis reveals the following relationships.

12 cu between #15 and #16
24 cu between #16 and #17
12 cu between #17 and #1
12 cu between #1 and 2
24 cu between #9 and #11
12 cu between #11 and #12

Several other points are noted on the chart, but the points listed above were easily identified and close to the vortex.

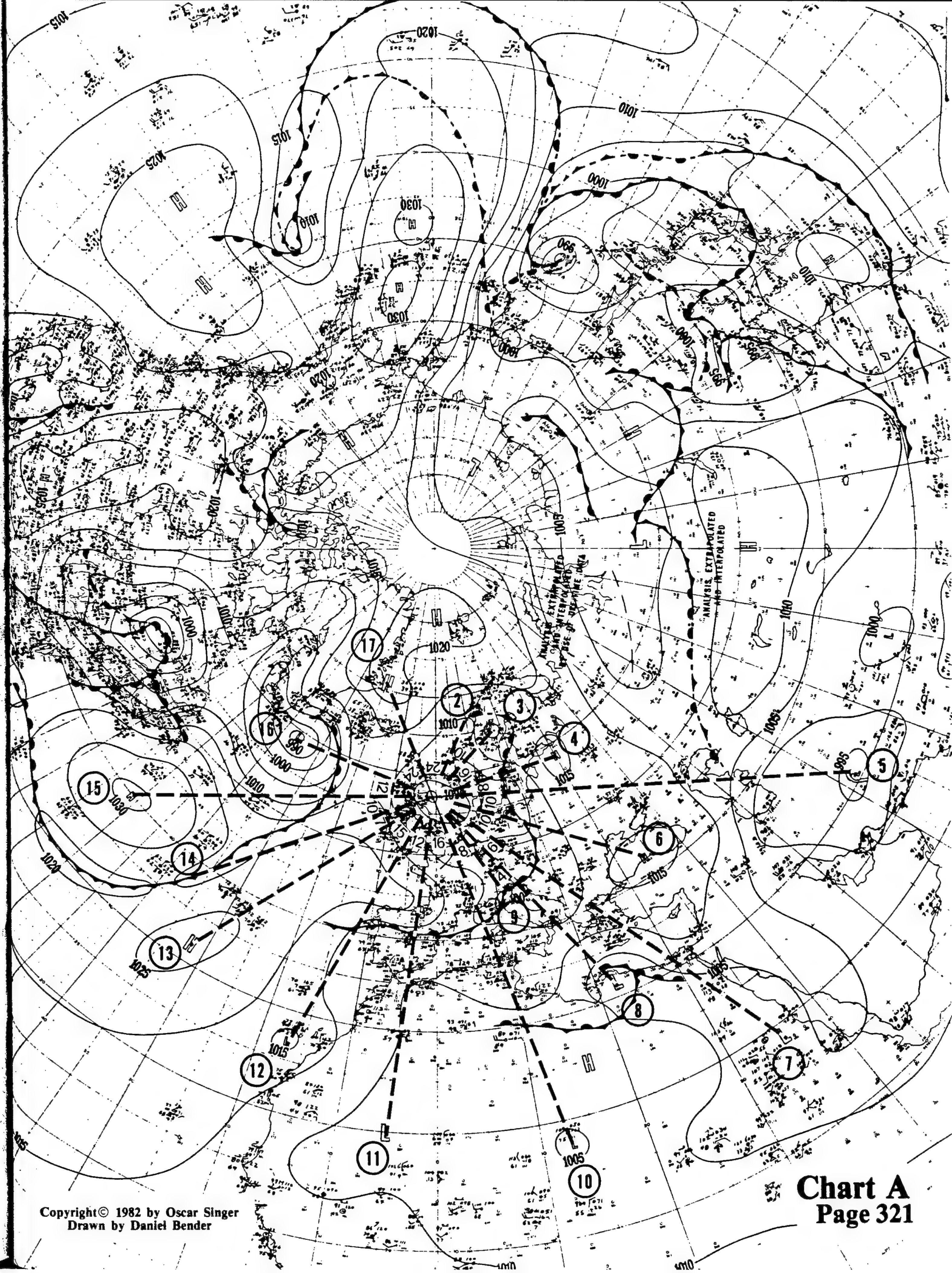

Chart A
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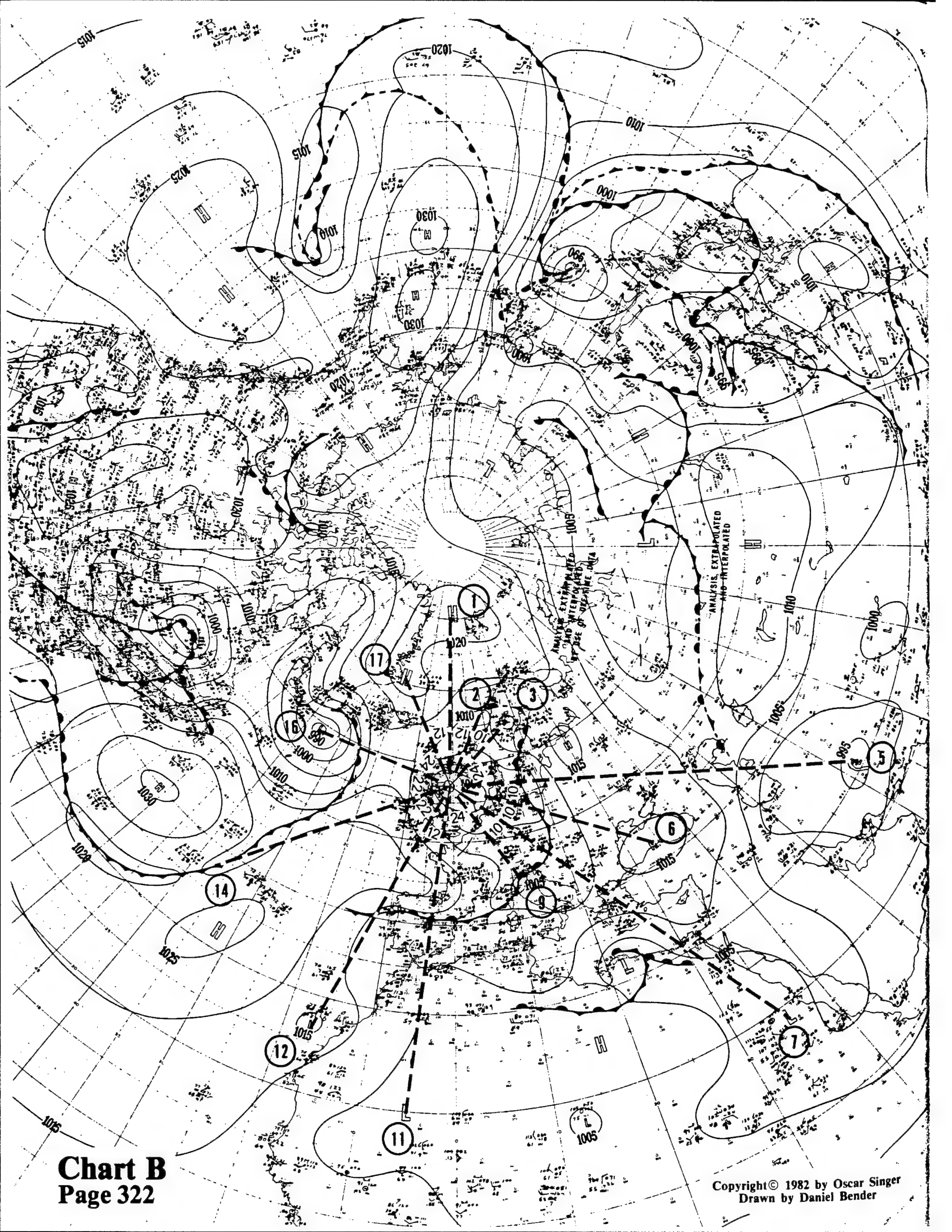

Chart B
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X. Summary/Comments.

Mr. Singer's book may be the first and only publication detailing the relationships of surface pressure systems. These charts show an obvious relationship in two separate and different analyzes-Radial and Circumferential.

I have two primary concerns, the manipulation of data to prove a relationship and the usefulness of this information to the operational meteorologists.

One may think that two days of charts isn't enough to form a basis or foundation for this relationship. But Mr. Singer's text only highlights these two days; he's actually noted these relationships on daily weather charts for numerous years. The relationship can only be questioned by some of the points used on these charts. While even Mr. Singer notes that some pressure center locations are obscure, the majority are well-defined and far out weigh the obscure points. Also we have to keep in mind that the atmosphere is a fluid and ever changing. Pressure centers must develop and die at some point. These developing, dying, and transition points should not be excluded.

So you just make an overlay and connect the dots, right? Although it may appear that easy, it of course isn't. Being the "let me try that" kind of person I am, I attempted to make some relationships on the summer charts by picking the 10 most well defined centers. Using one of his "weather tools" (he sells them) and a copy of a chart (Jun 6, 1944 Chart B) I did a circumferential analysis. Needless to say it wasn't as easy nor as clear cut as the work Mr. Singer shows, but I was able to show a relationship between 7 of the 10 locations chosen. See Figure 12 below and the following chart. So even a laymen with some fundamental tools can see a relationship exists. The real test would be to apply this relationship in an operational environment.

Point	Number	Relation Points	CU #	
1	105	10/1	40	4x10
2	91	1/2	14	
3	83	2/3	8	4x2
4	67	3/4	16	4x4
5	51	4/5	16	4x4
6	62	5/6	12	4x3
7	34	6/7	28	4x7
8	171	7/8	54	
9	155	8/9	16	4x4
10	145	9/10	10	

Figure 12
June 6, 1944 points using Chart B's center point.

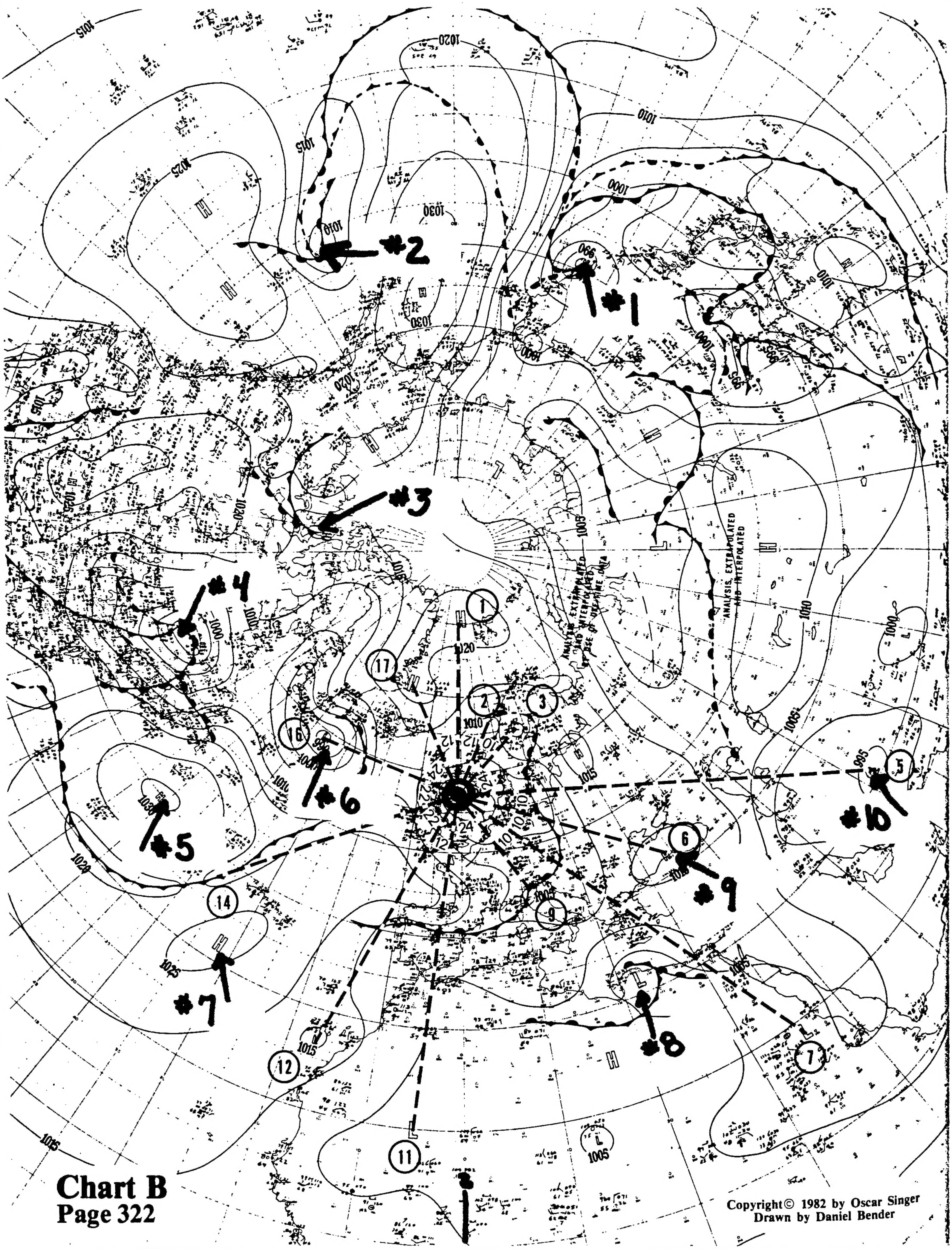

Chart B
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In an operational environment it's fairly obvious where a pressure system is, so one will probably only need to know where the pressure system is moving to. So the circumferential relationships may not be useful at all. I believe the radial distances may be of the most use. It would need to tie in the movement to the forecast period. To use this information effectively as a forecaster one would need to make several assumptions:

-A polar stereographic background is available with a surface analysis and in a timely manner.

-A proper weather "tool" to use as an overlay to determine the relationships

-A computer (and program) to crunch the numbers of Lat/Long and display current and forecast distances from positions

-Knowledge enough to use this information in a timely manner and to integrate this into current forecast techniques

National Weather Service has some fax charts available, although I'm not sure of the data coverage and timeliness of these products. These charts would have to be available in "hardcopy" to use this current technique (overlays). A tool would have to be created to use as an overlay. Any distortion of the diffraction overlay would give erroneous values. Mr. Singer does have a computer program to crunch the numbers for the initial positions, but this data would have to be updated continuously as data became available. To this point, Mr. Singer and his assistant are the only two knowledgeable enough to even attempt this if all the above criteria were met.

Mr. Singer has told me that he has been able to issue timely forecasts using his technique. But he is withholding the release of his technique pending a grant review. Until he releases his technique based on the relationships of his book, I don't believe there is any practical use of these relationships for the operational or practical meteorologist/forecaster. With that said, we must hope for his continued selflessness in the pursuit of his research. I look forward to the release of his procedures and have enjoyed the correspondence with him over the past year. His text is very well done and explains the fundamentals very articulately. I'm sure he'll soon get the acknowledgement/acceptance due from his years of study into the great field of meteorology.

There are hundreds of books, papers, and articles available discussing how to forecast movement of pressure systems. I believe weather forecasting is almost as much an art as it is a study of science. A satellite photo can be interpreted numerous different ways. Placement of a boundary or pressure center can vary by as much as a 100 miles, and still be technically correct. With that in mind LaSeur's comment[3] seems an appropriate closing.

"In the literature one encounters such diverse opinions and interpretations, often of essentially the same data, plus considerable speculation and unwarranted generalization or extrapolation of concepts and results of limited validity, that the resulting impression is one of disquieting confusion."

References

1. Singer's Lock, The Revolution in the Understanding of Weather, Part I, 1985

2. Numerous emails/correspondence and visit with Mr. Singer

3. N. E. LaSeur "Synoptic Models in the Tropics," In. Proc. of the Symposium of Tropical Meteorology, Rotorua, N.Z., Nov 1963, N.Z. Met. Service, 1964, pp. 319-328

4. Conversations with Dr. Dean Morss, Project Advisor.